Journal

WATER POLLUTION CONTROL FEDERATION

Special Features

Oil and Tar on Beaches—Ludwig and Carter

Industry-ORSANCO Cooperation—Rhodes et al.

BOD of Fatty Acids—Gaffney and Heukelekian

Swimmers in Aeration Tanks—Kershaw

Trace Organics—Sproul and Ryckman

Package Plant Operation—Howe

Public Information Materials

NOVEMBER 1961

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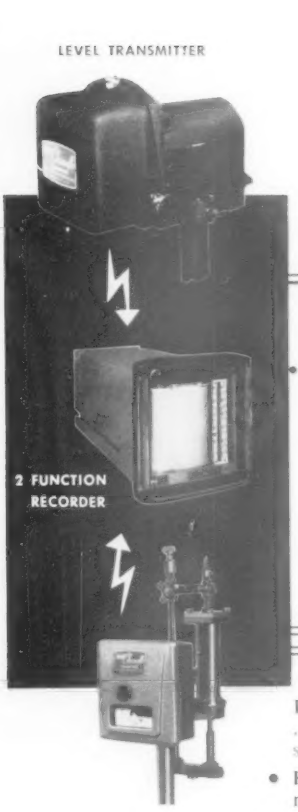

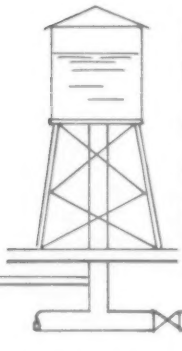

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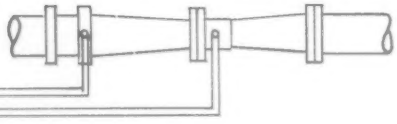

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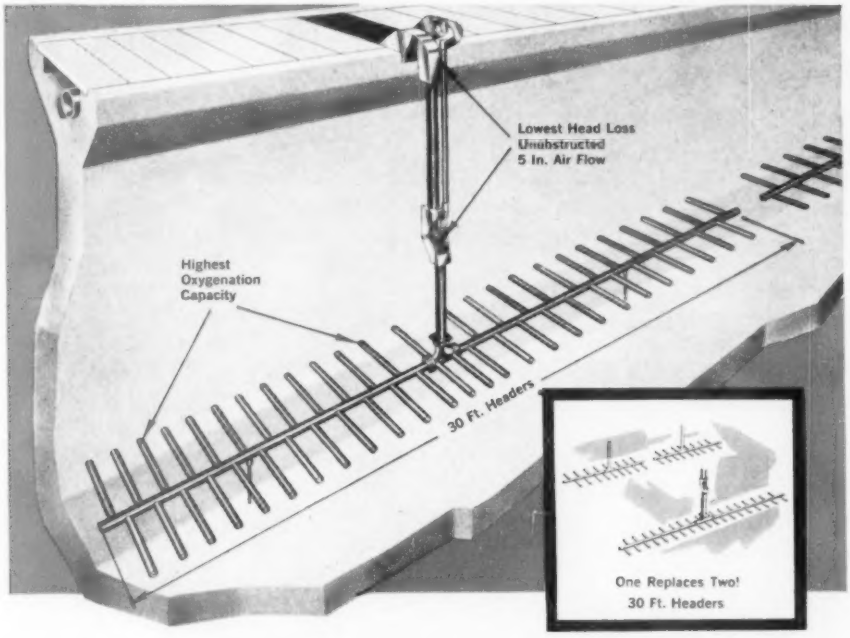

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Volume 33 November 1961 Number 11

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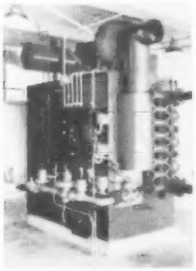

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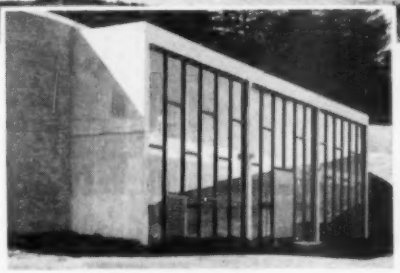

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EDITORIAL AND EXECUTIVE OFFICES: 4435 Wisconsin Ave., N.W., Washington 16, D. C. Send all manuscripts, advertising copy, subscriptions, address changes, etc., to this address. JOURNAL WPCF is published monthly by the Water Pollution Control Federation at Prince & Lemon Sts., Lancaster, Pa.

SUBSCRIPTION RATES: Members of local associations affiliated with the Federation: $8.00 per calendar year. All others, U. S. and Canada: $10.00 per calendar year; other countries, $11.50 per calendar year. Single copies: U. S. and Canada: $1.25 each; other countries: $1.50 each.

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REFERENCE SERVICE: JOURNAL of the WATER POLLUTION CONTROL FEDERATION is indexed regularly by *Industrial Arts Index* and *Engineering Index*. Microfilm copies of this JOURNAL may be procured from University Microfilms, Ann Arbor, Mich. This service is limited to regular subscribers only.

Library of Congress Catalog Card Number: 42-19992.

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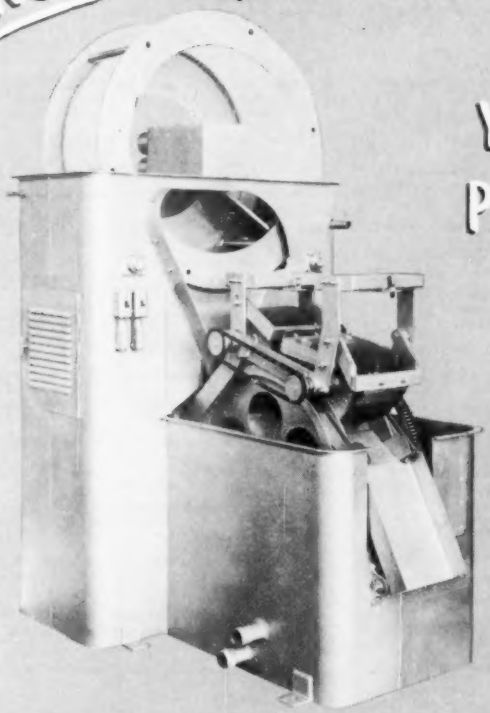

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QUALITY K-S EQUIPMENT

COILFILTER OPERATING DATA Month July

City of Beatrice, Nebraska Equiv. Pop. 12848 (Sus. Solids)

Chemicals vs Dry Wt. Solids				FILTER CAKE		pH sludge before chem	pH sludge after chem
Pounds Used		Percent Used		% Moisture	Yield lbs./sq. ft./hour		
Lime	$FeCl_3$	CaO	$FeCl_3$				
850	89	7.1	1.2	76	8.4	6.4	11.8
735	120	6.8	1.1	72	10.7	6.8	12.0
420	64	5.5	0.8	76	10.8	6.8	11.8
490	67	6.2	0.8	76	10.4	6.4	12.0
550	58	6.7	1.1	74	8.2	6.2	11.8
400	42	7.0	1.5	76	7.9	7.0	11.8
700	64	7.4	0.9	75	9.4	6.8	11.8
600	59	7.2	1.2	74	8.2	6.6	11.8
500	47	6.1	0.9	72	11.2	6.8	12.0
650	64	6.7	0.9	76	9.5	6.8	12.0
650	61	7.7	1.3	79	8.3	6.6	11.8
600	67	7.0	1.1	76	8.4	6.8	11.6
7145	802						
595.4	66.08	6.71	1.06	75.1	9.2	6.66	11.85

.82 (Tons) 3.57 (Tons)

**Note: PC for Primary Clarifier
HT for Holding Tank
D for Digester

MONTH'S AVERAGE

ER DEWATERING COST

Unit Cost	Cost per Month	Cost/ton dry wt.	Cost/capita/yr.
12.5¢	100.25	2.86	.093
1.2¢	85.74	3.32	.080
	185.99	6.18	.173

*For Filtration Operation Only

Signed: Wayne Bitting
Title: Water Supt.
Date: 8-8--60

The Beatrice, Nebraska, sludge dewatering report shown here is not unusual; it is representative of the scores of Coilfilter fresh solids dewatering installations throughout the country, as well as the hundreds of other Coilfilters dewatering digested or primary and trickling filter sludges.

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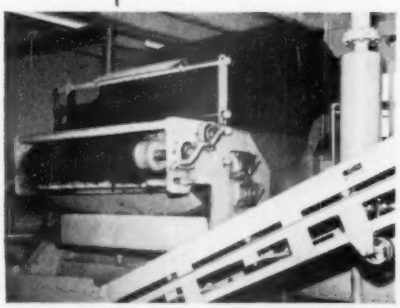

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Association *	*Date*	*Place*
Indiana	Nov. 15–16	Hotel Washington, Indianapolis
Oklahoma	Nov. 27–Dec. 1	Oklahoma State University, Stillwater
New York	Jan. 17–19, 1962	Park Sheraton Hotel, New York
Texas	Mar. 11–16	Texas A & M College, College Station
Louisiana	Mar. 14–16	Louisiana State University, Baton Rouge
New Jersey	Mar. 28–30	Traymore Hotel, Atlantic City
California	Apr. 25–28	Hotel Senator, Sacramento
Kansas	May 2–4	Lassen Hotel, Wichita
Arizona	May 3–5	Pioneer Hotel, Tucson
Michigan	May 21–23	Park Place Hotel, Traverse City
New England	June 6–7	Wentworth by Sea, Portsmouth, N. H.
Central States	June 20–22	Hotel Duluth, Duluth, Minn.

* See preceding left-hand page for full name.

THIRTY-FIFTH ANNUAL MEETING

Water Pollution Control Federation

HOST—Canadian Institute on Sewage and Sanitation

Toronto, Ontario, Canada

Royal York Hotel

October 7–11, 1962

ECONOMICAL B.O.D. REMOVAL BY "TOTAL OXIDATION" SEWAGE PLANTS

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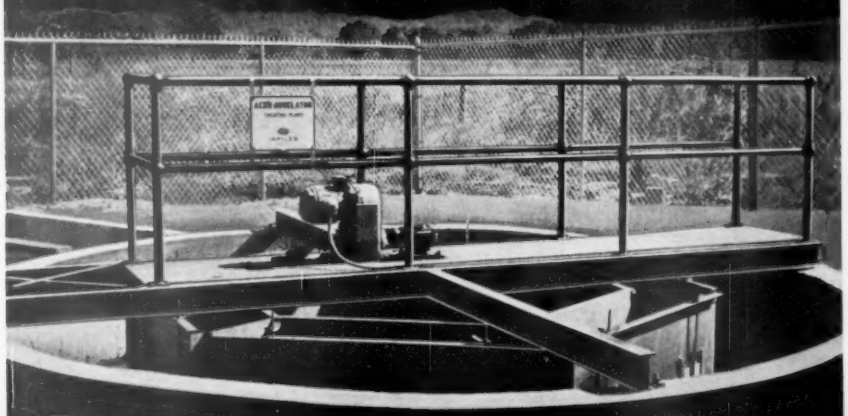
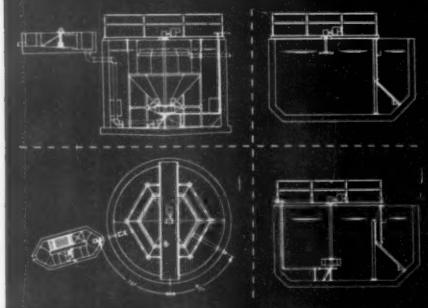


Typical ACCELO-BIOX® plants



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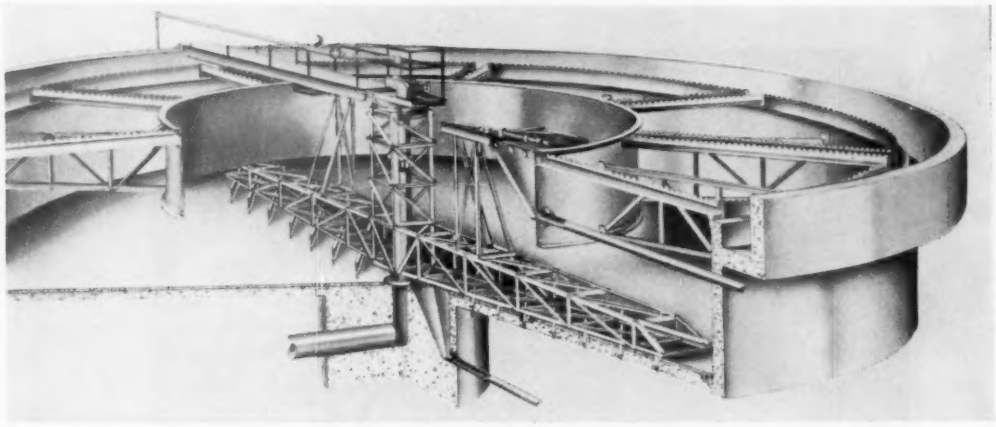
GET RID OF SLOW-SETTLING SOLIDS FAST...

EIMCO-PROCESS FLOTATOR-CLARIFIER® TREATMENT UNIT

HOW SOLIDS ARE REMOVED . . .

Eimco-Process Flotator-Clarifier units combine dissolved air flotation and conventional sedimentation in a single tank. Slow-settling solids — and solids tending to remain in suspension — are removed by flotation. Rapid treatment, in less clarification area.

Eimco - Process Flotator - Clarifier unit installed at Fairfield - Suisun, California, Sewage Treatment Plant. Solano Engineers, Associated, Vallejo, California, Consultants.



HANDLES MANY TYPES OF WASTES...

Flotator-Clarifier units have been installed for primary clarification of sewage . . . for removing and recovering finely divided solids and low specific gravity liquids from industrial process waters.

REDUCES TREATMENT COSTS...

Pressurization of influent or recycle or part of the effluent pressurized with air speeds the flotation of near-colloidal particles . . . results in fast solids removal and maximum economy of operation.

SAVES SPACE AND TANK COSTS...

Suspended solids removals equivalent to those of a conventional clarifier are obtained in about half the tank area.

HANDLES WIDELY VARYING FLOWS...

Eimco - Process Flotator - Clarifier units are built with a number of design innovations that enable the unit to handle waste surges, yet operate efficiently during periods of low flow.

REDUCES PLANT ODORS...

Treatment is fast and efficient. Long detention periods are eliminated. Septicity and objectionable plant odors are greatly reduced.

Ask the Eimco-Process representative in your area for more details. And write Eimco's Process Engineers Division for Bulletin PJ-1008.

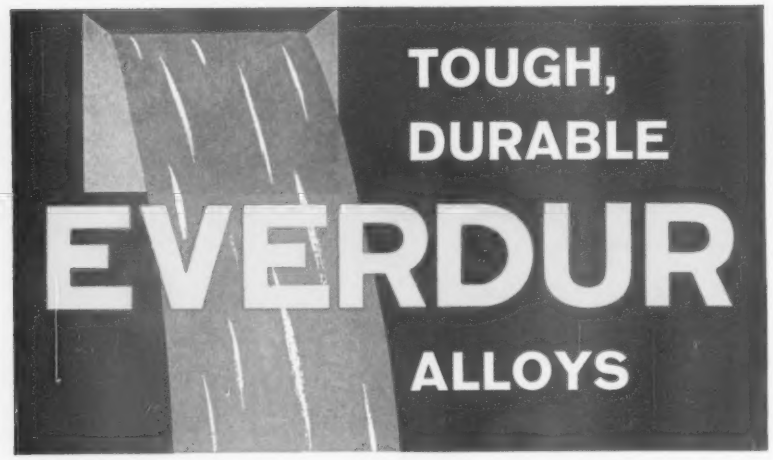
Flotator is a trademark of The Eimco Corporation.

EIMCO

"Advanced Engineering and Quality Craftsmanship Since 1884"

Process Engineers Division
420 Peninsular Avenue,
San Mateo, California

B 789



highly resistant to wear and abrasion in sewage and water works systems

EVERDUR® copper-silicon alloys have excellent resistance to corrosion in all types of water works installations and at all stages of sewage treatment operations. EVERDUR equipment in the United States has been in service *without replacement* for 30 years and longer.

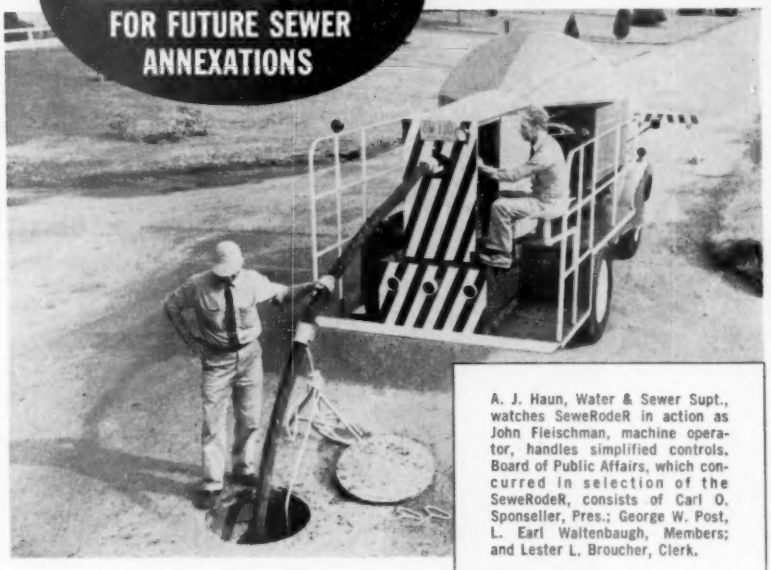
Easily fabricated EVERDUR provides high physical strength with lighter weight. It is used extensively in sewage systems handling corrosive wastes in screens, stems, manhole steps, guides, bolts, weirs, float chambers, troughs. And for water works equipment you will find EVERDUR alloys in long service as surface reservoir outlet screens and screen frames and as large diameter cylindrical well screens in drilled well supply systems. Other uses: spillway fittings, guides, seats and sealing strips. And don't forget EVERDUR Electrical Conduit for use in corrosive atmospheres.

Publication E-11 shows typical applications and other data. Write for your copy—or for assistance from our Metallurgical Dept. in selecting the proper corrosion-resistant alloys for your equipment. Address: Anaconda American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Canada. 61-B11

EVERDUR®
a product of
ANACONDA®
AMERICAN BRASS COMPANY

NORTH CANTON'S NEW SEWERODER HAS RESERVE CAPACITY FOR FUTURE SEWER ANNEXATIONS

Ohio's new city gears up for growth



A. J. Haun, Water & Sewer Supt., watches SeweRodeR in action as John Fleischman, machine operator, handles simplified controls. Board of Public Affairs, which concurred in selection of the SeweRodeR, consists of Carl O. Sponseller, Pres.; George W. Post, L. Earl Waltenbaugh, Members; and Lester L. Broucher, Clerk.

Rapid growth during the past ten years resulted in North Canton, Ohio becoming a City in 1961. Even faster growth is anticipated through annexations, and the City officials have wisely taken this into account by long range planning.

A major problem created by the rapid expansion is the ability to provide adequate sewer cleaning service for today's needs, plus reserve capacity for the future. After careful investigation, Water & Sewer Supt. A. J. Haun found that by purchasing and truck-mounting a SEWERODER, a single rodding crew could easily maintain the entire system on a preventive maintenance basis. He says, "we find the SEWERODER to be the easiest machine to set up and operate that we have ever had."

The SEWERODER's superior performance is made possible by many unique and exclusive features, such as positive non-slip rod drive, automatic safety clutch, instantly reversible push-pull power. All rods are self-contained in the machine and operating controls are conveniently located. Set-ups are made from street surface by merely lowering the hose guide into the manhole by means of a rope.

FLEXIBLE Inc.

415 South Zangs Blvd., Dallas, Texas
3786 Durango Ave., Los Angeles 34, Calif. • 1005 Spencerville Road, Lima, Ohio

Rugged pipe installs easily

—even in a soggy bed

This 30" cast iron pipe was installed for expansion of a water system in Memphis, Tennessee.

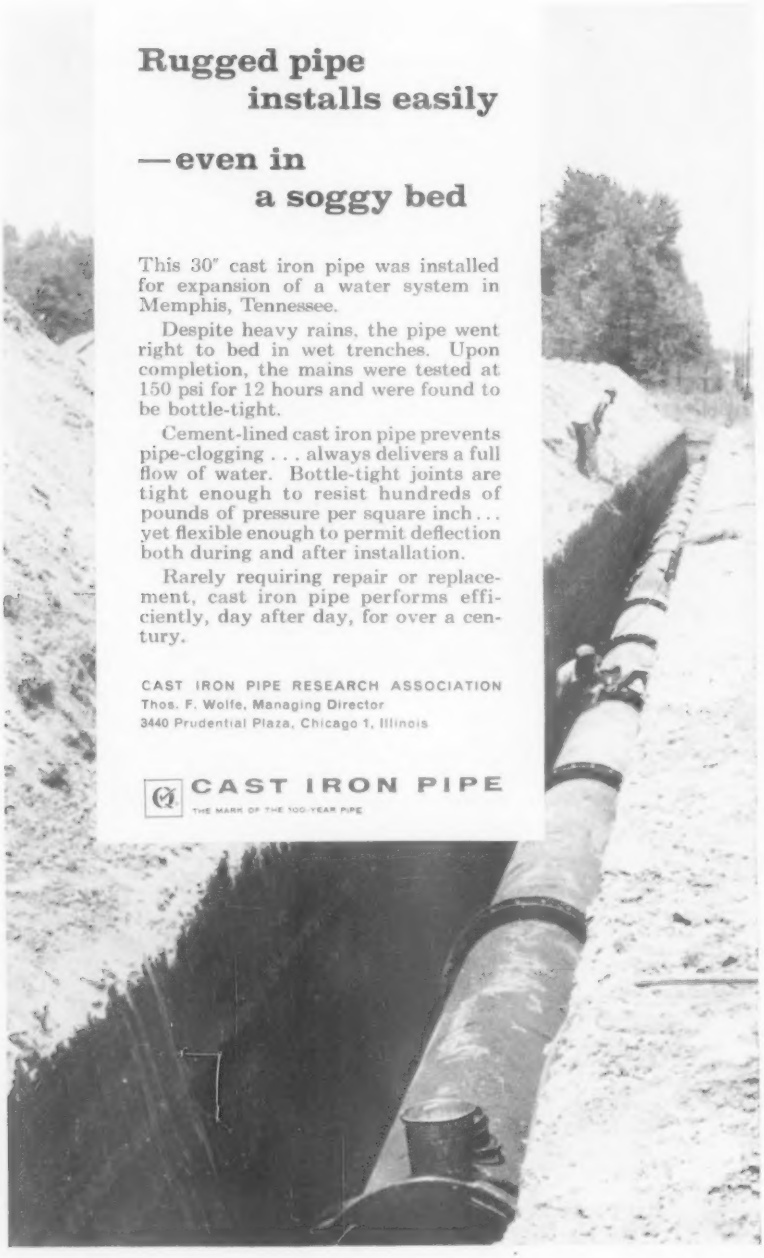
Despite heavy rains, the pipe went right to bed in wet trenches. Upon completion, the mains were tested at 150 psi for 12 hours and were found to be bottle-tight.

Cement-lined cast iron pipe prevents pipe-clogging . . . always delivers a full flow of water. Bottle-tight joints are tight enough to resist hundreds of pounds of pressure per square inch . . . yet flexible enough to permit deflection both during and after installation.

Rarely requiring repair or replacement, cast iron pipe performs efficiently, day after day, for over a century.

CAST IRON PIPE RESEARCH ASSOCIATION
Thos. F. Wolfe, Managing Director
3440 Prudential Plaza, Chicago 1, Illinois

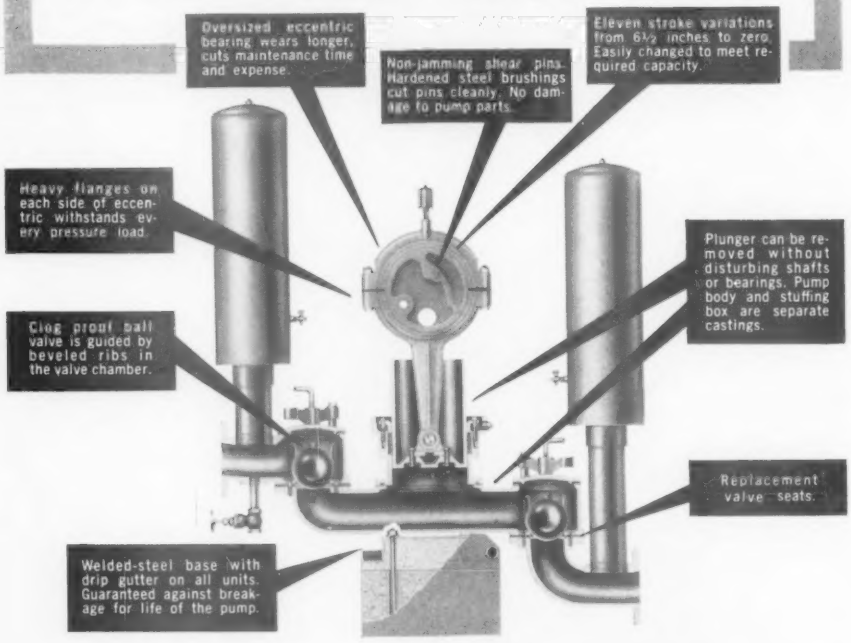
CAST IRON PIPE
THE MARK OF THE 100-YEAR PIPE



LOOK AT THE ADVANTAGES

you get with *Marlow* plunger pumps

for more efficient sludge handling!


Oversized eccentric bearing wears longer, cuts maintenance time and expense.
Non-jamming shear pins. Hardened steel brushings cut pins cleanly. No damage to pump parts.
Eleven stroke variations from 6½ inches to zero. Easily changed to meet required capacity.
Heavy flanges on each side of eccentric withstands every pressure load.
Plunger can be removed without disturbing shafts or bearings. Pump body and stuffing box are separate castings.
Clog proof ball valve is guided by beveled ribs in the valve chamber.
Replacement valve seats.
Welded-steel base with drip gutter on all units. Guaranteed against breakage for life of the pump.

PLUS...

1. Constant out-put despite changing head conditions.
2. High pressures when needed to free clogged lines.
3. Self priming . . . no auxiliary priming equipment required.
4. Rugged construction . . . stones, metal slugs can not harm pump parts.

find out how Marlow Plunger Pumps can solve your sludge handling problem. Start now by writing for catalog W-59 and complete information.

Marlow PUMPS

MARLOW PUMPS

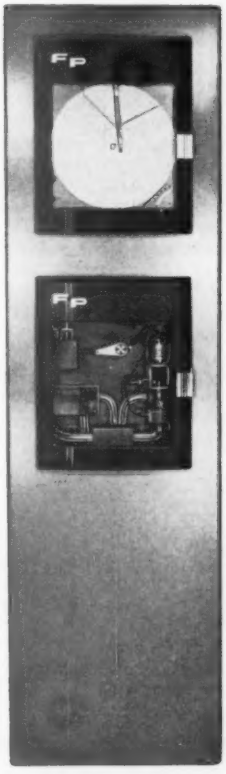
Division of Bell & Gossett Company

MIDLAND PARK, NEW JERSEY

Longview, Texas • Morton Grove, Illinois

C-567

■ Here is the **Anachlor*** – the residual chlorine analyzer that's also an efficiency expert on water or sewage treating operations. It continuously measures Cl_2 residuals, frees personnel from routine checks, and saves on the cost of treatment chemicals. The Anachlor has two basic components, the analyzer unit where current proportional to the chlorine is generated, and the recorder or indicator with optional electric or pneumatic control elements. It can trim chlorinator feed rate and also transmit measured values to a remote station. It employs an electrode rotating at high speed so that a high velocity of sample flow is not necessary. The electrode cell is easily disassembled for cleaning by disconnecting one slip-on connection and two pins. You'll find the Anachlor equally suitable for water or sewage treating operations – easy to operate – easy to maintain – and thoroughly dependable.



The Anachlor is described in complete detail, from operating principles to control options, in Catalog 17B2200. This instrument is only one of many F&P components for automating water and waste treatment. For basic information or specific suggestions write Fischer & Porter Company, 1211 Fischer Road, Warminster, Pa. In Canada, write Fischer & Porter (Canada) Ltd., 2808 Jane Street, Toronto.

F P
FISCHER & PORTER COMPANY
CHLORINATION AND INSTRUMENTATION

*Anachlor is a trade name of Fischer & Porter Company

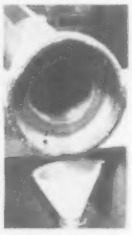
only CLAY meets the ACID TEST!

Unretouched* photos show corrosion damage caused by the flow of acid solution.

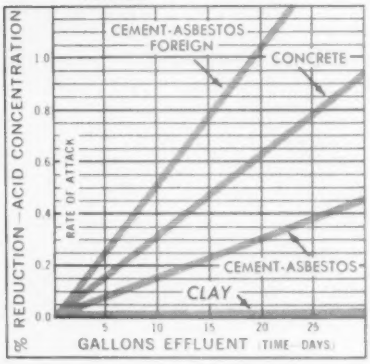
CEMENT-ASBESTOS

CONCRETE

CEMENT-ASBESTOS FOREIGN



CLAY



It's sulphuric acid that destroys sewer lines made of materials bought as substitutes for lifetime Vitrified Clay Pipe. And sulphuric acid—which combines chemically with the binding material in other products to disintegrate them—can't hurt Vitrified Clay, a completely inert material.

Special tests at the Clay Pipe Industry's modern laboratory at Crystal Lake, Illinois, recently illustrated just how damaging this acid concentration can be.

As you can see in these photographs and the chart, the acid started eating up the substitute materials quickly. But it didn't do a thing to lifetime Vitrified Clay.

It's a simple test. Try it yourself before you specify any product for your sanitary sewers other than Vitrified Clay. We just pumped 30 gallons of 8.6 percent sulphuric acid by weight through four different pipe specimens—in this case, domestic cement-asbestos, concrete, foreign cement-asbestos and clay.

Remember, you can't argue with the facts, and you can't repeal the laws of science. Sewer gas and oxygen are present in all sanitary sewers. And sewer gas and oxygen combined add up to sulphuric acid, which destroys substitutes for Vitrified Clay Pipe.

*Manufacturers' brand names deleted.

NATIONAL CLAY PIPE MANUFACTURERS, INC.
1028 Connecticut Ave., Washington, D. C.

Please send me full details on the results of the acid tests on the four sewer pipe materials shown here.

(name)

(company)

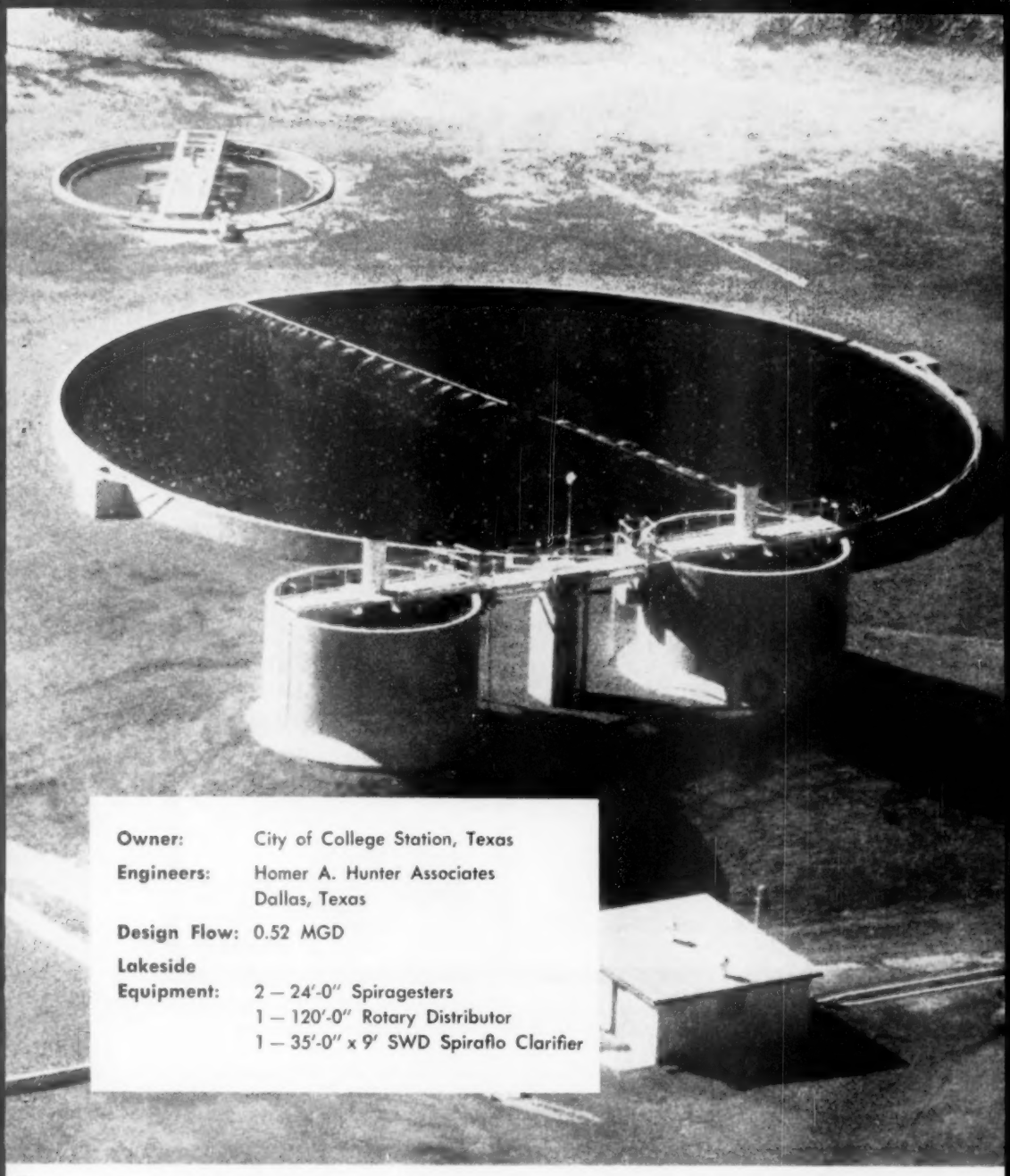
(street address)

(city and state)

8-61 WP

COMPRESSION SEALED, VITRIFIED
CLAY PIPE
IMPERVIOUS
THE STANDARD in SANITARY SEWERS

NATIONAL CLAY PIPE MANUFACTURERS, INC.
1028 Connecticut Avenue
Washington 6, D. C.



Owner:	City of College Station, Texas
Engineers:	Homer A. Hunter Associates Dallas, Texas
Design Flow:	0.52 MGD
Lakeside Equipment:	2 — 24′-0″ Spiragesters 1 — 120′-0″ Rotary Distributor 1 — 35′-0″ x 9′ SWD Spiraflo Clarifier

SPIRAGESTERS® are used singly for projects under 6000 P.E. They give superior results with the minimum of operating skill. Construction and operating costs are among the lowest. Plant expansion available by adding another Spiragester or easily converting the tank to a digester. Spiragesters are now installed throughout the U. S. Also Canada and foreign countries. As at College Station, Lakeside provides trickling filter and Spiraflo final clarifier equipment for a complete treatment plant. *Write for Bulletin 100.*

LAKESIDE

ENGINEERING CORPORATION

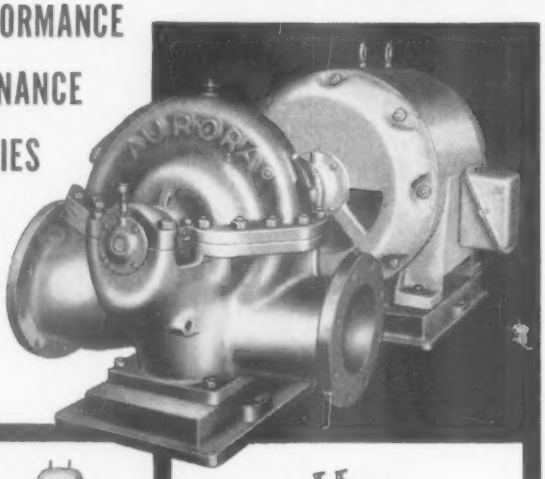
222 West Adams St. Chicago 6, Illinois

AURORA® Split Case

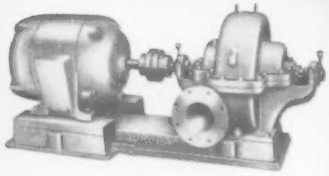
CENTRIFUGAL PUMPS

with

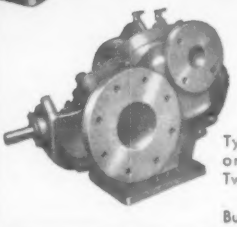
- SMOOTH PERFORMANCE
- EASY MAINTENANCE
- HIGH CAPACITIES



Type OJ Horizontally Split Single Stage Double Suction. Bulletin 105-B.



Type AJ Horizontally Split Two Stage Opposed Suction. Bulletin 106-B.



Type AJ Diagonally Split Two Stage

Bulletin 106-DS

- Smooth, dependable performance and long life is assured with streamlined liquid flow, scientifically balanced impellers, perfect alignment, large shaft sizes, short bearing centers and low NPSH.
- Maintenance is fast and easy . . . both suction and discharge are on bottom half of case . . . piping and motor-pump alignment is never disturbed.
- Capacities to 600 GPM . . . Heads to 600 feet.

IDEAL FOR: Water Service • Boiler Feed • Circulating • Cooling Tower • Pressure Build-Up • Fuel Transfer • Boosting to Pressure or Elevated Tanks • Many General Applications.

FOR COMPLETE INFORMATION WRITE—OR CALL

AURORA Always PUMPS

AURORA PUMP DIVISION
THE NEW YORK AIR BRAKE COMPANY ®
1190 LOUCKS • AURORA, ILLINOIS

LOCAL DISTRIBUTOR IS LISTED IN THE YELLOW PAGES OF YOUR PHONE BOOK

SIMPLIFIED BY SIMPLEX

Simplified by Simplex: New Float in Flume meter measures with great accuracy the flow of various kinds of liquids in channels, sewers and other gravity flow systems — and radically slashes construction costs.

New "Float in Flume" obsoletes the stilling well— saves you its construction cost

Now you can measure open channel or sewer line flow accurately without a stilling well—but at a fraction of the construction, installation and maintenance costs.

The "Float in Flume" is simplicity itself. A vane, floating atop the liquid passing through the flume, senses the liquid level. This data is transmitted through a Simplex transmitter-receiver system (pneumatic or electric), and is translated into flow terms on a modern, easy to read Simplex type "L" meter.

You save all the costs formerly required by a stilling well: the extra excavation and concrete, float pipe, grating, valves, drain pipe and fittings, cleaning valve and sediment chamber.

You don't even need a purging system. An occasional wiping of the vane is all the cleaning required.

The Float in Flume transmitter may be installed in existing flumes or is furnished assembled with a Simplex Type "S" Parabolic Flume as shown above.

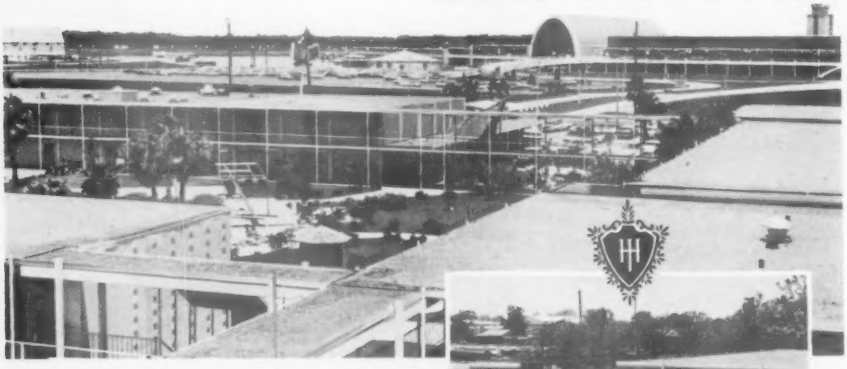
Before you install another meter requiring a stilling well, check the savings of the Float in Flume meter. Drop us a note today and ask for Bulletins 726 and 728.

Simplified by Simplex: New Type "L" Meter is more modern, more compact. Big red-and-white helical indicator replaces pointer, makes reading easier. Continuous type totalizer unsurpassed for accuracy. All parts are mounted on swing-out panel for easy servicing.

SIMPLEX® VALVE AND METER CO.
LANCASTER, PENNSYLVANIA
a division of
PFAUDLER PERMUTIT INC.

We're proud to count the beautiful Jet-Age **Hilton Inn**

ACROSS FROM INTERNATIONAL AIRPORT
NEW ORLEANS



among our **"OXIGEST"** *sewage treatment plant installations . . .*

S&L

The 310-unit Hilton Inn Motor Hotel at Kenner, Louisiana, is served by dual "Oxigest" sewage treatment plants, capable of handling 40,000 gallons of domestic sewage per day. The treatment facility was designed by Edward H. Sanford & Associates, Consulting Engineers, New Orleans, La., and was installed over two years ago.

We are pleased to include the Hilton Inn in our growing list of factory-built treatment plant installations at motels, schools, factories and subdivisions . . . write to Department 30

Smith & Loveless

"We, in the Hilton organization, appreciate the responsibility Smith & Loveless has assumed in the operation of the Hilton Inn treatment facility. It is gratifying to know that your firm backs its equipment with such responsibility and service. Our engineers report that the treatment plant is performing in accordance with all specified guarantees and local and state health department requirements." . . . *C. N. Hilton, Jr., Vice President, Hilton Inns, Inc.*

"Because of the unusual efforts your company has expended on this installation, and your continued interest in the satisfactory function and performance of the plant, we express our sincere appreciation to you." . . . *Edward H. Sanford & Associates*

UNION TANK CAR COMPANY

P. O. BOX 6884 / KANSAS CITY 15, MISSOURI / PLANT: LENEXA, KANSAS

(2850)

Pilot plants are are 28′ high, 3′ in diameter. They come completely assembled, with nutrient feeder, pumps and other equipment ready for connection and immediate use.

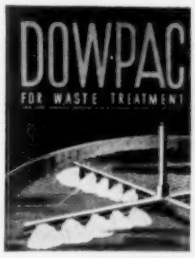
LOW-COST PILOT PLANT USING NEW DOW DEVELOPMENT CAN HELP SOLVE YOUR WASTE TREATMENT PROBLEMS!

Now, at little cost, you can install a trickling filter pilot plant using new Dowpac® biological oxidation media. This research tool will show you precisely how you can treat wastes efficiently . . . and how best to do it . . . under *your actual operating conditions*. Data obtained from pilot plants can be used for later scaling-up to full size—but compact—installations.

D.I.S. will lease or sell pilot plants, as you wish. D.I.S. engineers will assist in installing the plant, put it in operation for you, and interpret collected data to work out the most effective treatment for your particular problem.

Dowpac provides conditions approaching the design ideal for trickling filter-type systems, including light weight, to permit land-saving vertical construction . . . tremendous surface area for maximum bacteria growth . . . minimum of plugging or channeling . . . and practically no maintenance.

Write for new booklet on Dowpac, and for information on low-cost pilot plants. D.I.S. engineers will be glad to work with you to develop the most effective method for water and waste treatment for your particular conditions. Write DOW INDUSTRIAL SERVICE, 20575 Center Ridge Road, Cleveland 16, Ohio, Dept. JWPCF11.



Dowpac is a trademark for packing media—not pilot plants.

DOW

DOW INDUSTRIAL SERVICE

Division of The Dow Chemical Company

Mirrors, rectangles, and other tremendous trifles make Shone® your bargain buy in sewage ejectors

Would you like to hear more about how these and other design subtleties which make Shone the startling bargain in sewage pumping equipment? Call your Yeomans representative. He's in the Yellow Pages.

When 91 years of engineering and experience go into a **sewage pumping device**, there can be only one result—an ejector that is so much in a class by itself, it becomes an "institution" . . . a piece of equipment that keeps other ways of handling sewage **perennially obsolete** . . . a mechanism that makes embarrassing service interruptions and dangerous climbing in-and-out of manholes things of the past. Each part, each material, each contour, each surface of the Shone ejector has significance in the vital job of handling sewage.

1. Consider the **mirror-like** "superfinish" (you can **actually shave** in it) surfaces of the pilot valve slides and seat of the Shone's exclusive control system. Hand-lapped to perfection . . . only the weight of the valve slide plus pilot air pressure maintain the seal for decades of operation. Faces of the two parts fit so accurately that it is actually difficult to pull them apart. There is no leakage . . . opening and closing are truly positive. Parts do not wear "out of balance," because they are "broken in" before leaving the factory.

2. Piston valve and **pistons** are also "superfinished" to the same mirror-like surface . . . and a test of **each** valve assembly assures operation at only 60% of the **minimum** allowable pilot and operating pressure.

3. Or consider the singularity of **rectangular** valves in round pipes. Sticks and stones in sewage may "bridge" in a round pipe under low-flow conditions. Not only are the Shone's valves rectangular, but they have a larger internal cross section than the pipes to which they are connected. This is one of several reasons why **nothing** (but nothing) can choke a Shone ejector in this "bottleneck" spot. Anything which reaches the receiver passes through it and through the discharge valve.

4. We all know cotter pins are fine on tricycles (and on **external** linkage), but not inside pneumatic ejector inlet and discharge valves. You can't find a more perfect snagger for rags and other strangulating debris. Shone has flush-driven pins on valve hinges, another tremendous trifle.

5. A newly-cast, iron receiver, like any good whiskey, needs to be aged. Receivers for Shone pneumatic ejectors are "mellowed" for up to one year. This settles them down, prevents cracks and warping by relieving internal stresses in the crystal structure. Remember that Shone sewage ejector installations are usually considered permanent — the **first U. S. installation, 1889, is still in service.** An important invisible extra!

6. There are no "missing links" in the control linkage assembly of a Shone ejector. **Each** assembly is set, tested, dowled, and "match-marked" for its **own** particular receiver assembly. No trial and error fitting on the job. Another Shone "intangible" asset.

7. Tipsy control rods are obviously going to be less than 100% efficient. Shone bell rods are sober, straight, and only work with or against the forces of the bells and gravity. There is **no** side thrust to deform the packing seal. A trifle? No, a reason why Shone packing boxes go **years** without repacking.

8. Today, nothing is truer than "time is money." A special cast iron header, job tailored for each unit, holds field fitting, pipe cutting, etc., to bare necessities. Duplex units are complete with cross connections. The installer spends his time installing!

YEOMANS

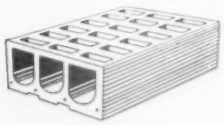
1999-7 North Ruby Street
Melrose Park, Illinois

WASTE HANDLING SPECIALISTS FOR OVER 60 YEARS

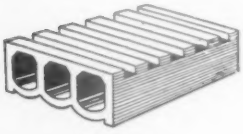
E-6142

Don't be a Guinea Pig—

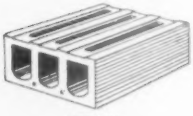
Insure Against Future Treatment Plant Trouble



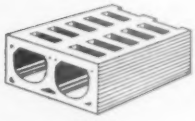
DICKEY
W. S. Dickey Clay Mfg. Co.
Kansas City 6, Mo.



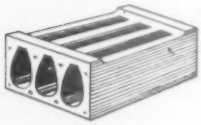
TRANSLOT
Cannelton Sewer Pipe Co.
Cannelton, Ind.



POMONA
Pomona Terra-Cotta Co.
Pomona, No. Car.



BOSCO
Bowerston Shale Co.
Bowerston, Ohio



NATCO
Natco Corporation
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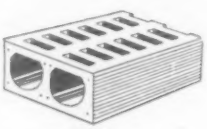

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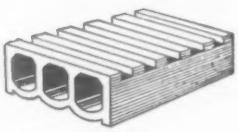

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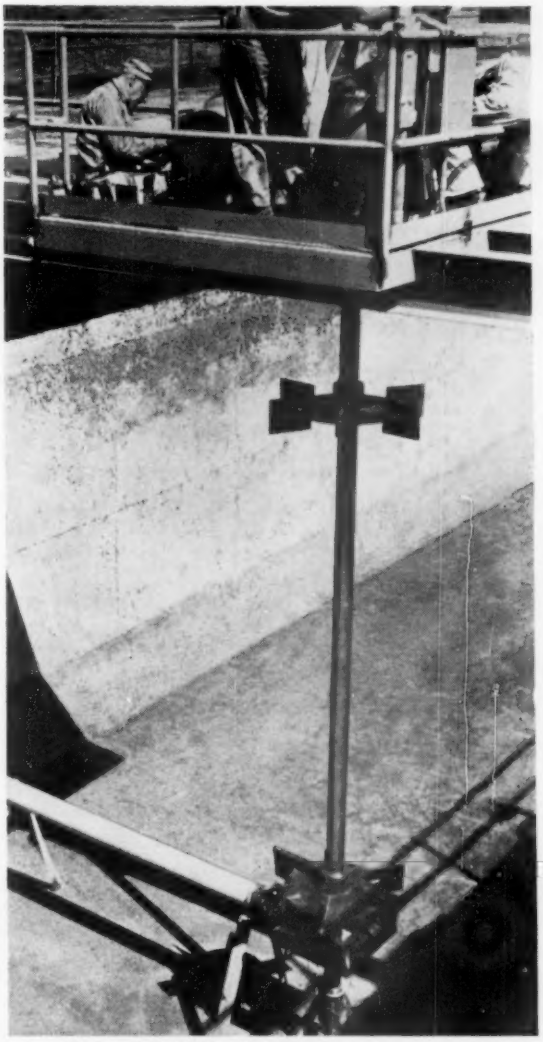

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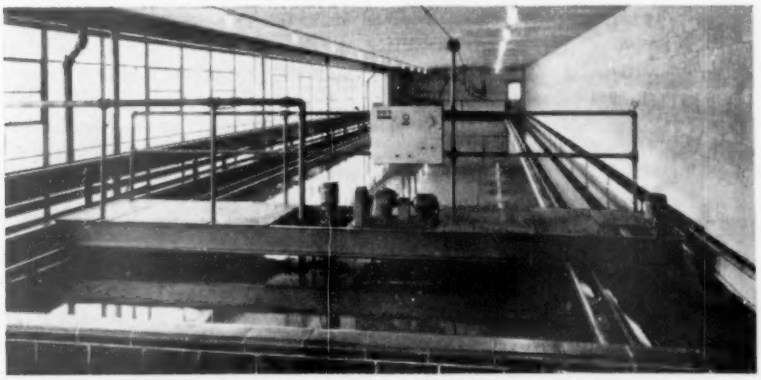

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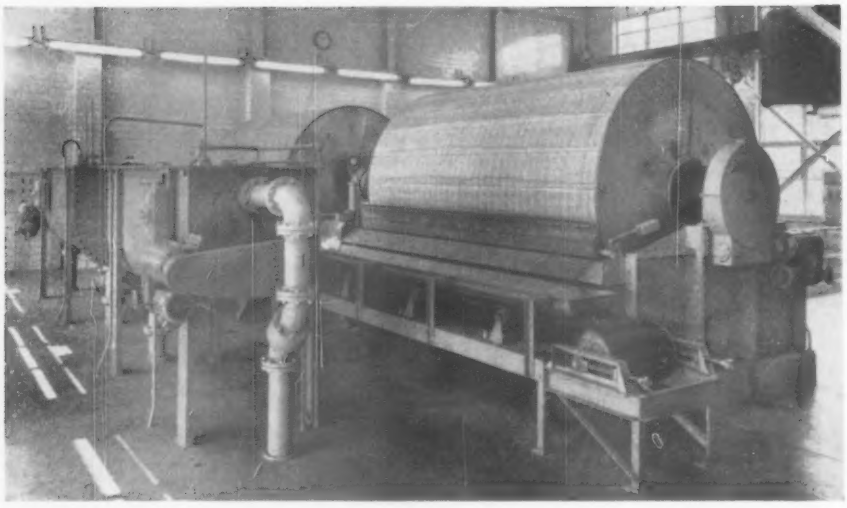

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ANALYTICAL CHARACTERISTICS OF OIL–TAR MATERIALS ON SOUTHERN CALIFORNIA BEACHES

Harvey F. Ludwig and Ralf Carter

One of the common characteristics of beaches in oil-producing areas, such as Southern California, is the periodic deposition of oil-tar materials having their origin in natural offshore seeps. Because these beaches may also receive deposits of oil and tar materials originating from non-natural sources (such as offshore wells, tankers, and sewer outfalls), much interest has developed in Southern California on practicable means for characterizing and distinguishing between these several classes of materials.

In 1957 a study program for sampling and analysis of oil-tar beach deposits in Southern California was initiated. This work included development of analytical methods for chemical charaterization of these materials (1). In 1959 an additional program was begun, involving the quantitative sampling and chemical characterization of oil-tar materials collected from six different Southern California beaches over a period of one year (May 1959 through April 1960). The findings of this second study (2) are reported in this discussion.

Beach Sampling Stations and Methods

The locations of the six coastal sampling stations, shown in Figure 1, were selected to represent a variety of different beach conditions and also a variety of different proximities to known offshore tar seeps. Figure 2 shows views of the stations. Selections were limited to places characterized by a uniform expanse of beach (not adjacent to jetties, coves, etc.), the absence of artificial cleaning, and absence of extreme currents or tides. The six stations were numbered as follows: 1. Sunset Beach, 2. Torrance County Beach, 3. Mussel Shoals, 4. Summerland Beach, 5. Coal Oil Point, and 6. Gaviota Beach. Two sampling plots were located at Sunset Beach, about 500 ft apart, designated Stations 1A and 1B, for the purpose of comparing data obtained from two nearby plots on the same beach.

The test plots at five of the six stations extended 100 ft along the beach and reached from the water's edge at low tide to the high tide level. At Coal Oil Point, where the magnitude of the deposits was relatively great, the length of the test plot was reduced from 100 to 6.0 ft. The plots were limited to these sizes primarily by the time required to collect the oil-tar samples (30 to 60 min for 1,000 sq m) and the gross amount of sample to be collected (usually between 100 and 3,000 g). The 100-ft long plot represented an area of approximately 1,000 sq m, and yielded information such that 90 per cent of all samplings of deposits ranged in weight between 18 and 180 per cent of the average deposits of several stations in the area.

Procedure

All visible particles of oil-tar deposits were manually picked up or scraped from rocks, seaweed, or other beach artifacts. As much of the debris

Harvey F. Ludwig and Ralf Carter are consulting engineers with Engineering-Science, Inc., Arcadia and Oakland, Calif.

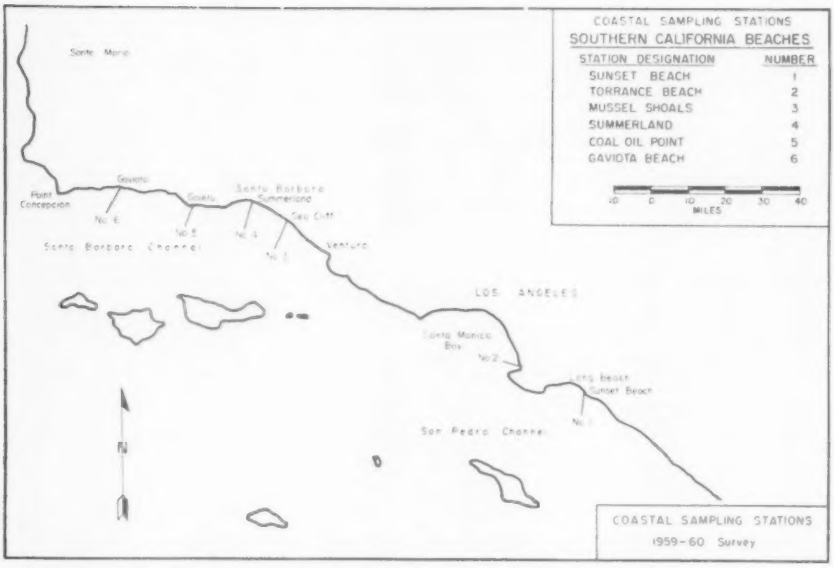


FIGURE 1.—Coastal sampling stations on Southern California beaches.

as could be easily separated by hand was discarded, with the remainder packaged and shipped to the laboratory.

In instances when the sampling area contained a large number of tar "bead drops" and/or a significant amount of oily film, these materials were collected by removing the top 0.5 cm of the surface layer of sand. When the film deposits were of limited extent, the sand surface for the entire area of the deposit was collected, quartered down to a volume convenient for transport to the laboratory, and there extracted and mixed with the extract from the regular oil-tar sample in suitable proportions. Where the entire portion, or a large portion, of the sampling plot contained an oily film deposit, a 5-cm strip of sand extending from the water's edge to the high tide level was collected.

Precision and Frequency of Sampling

With respect to the precision and accuracy of sampling oil-tar deposits collected by manual pickup, Merz (1) reported an accuracy of 90-per cent oil-tar recovery. In the present study the coefficient of variation for oil-tar recovery was determined to be 11.9 per cent. Hence, for a beach deposit averaging 0.2 g/sq m, 9 of 10 samples collected from the beach would show quantities of tar within the limits of 0.152 to 0.248 g/sq m.

Samples were collected once every month over a period of one year. Sampling was conducted on days when a low tide occurred between 1200 and 1400 hours.

Classification of Beach Deposits

The literature contains many references to oil-tar materials from seeps in the Los Angeles and Santa Barbara areas of Southern California, but no mention of classification of this material was found. A brief summary by Emery (3) of the history and present knowledge of California seeps was published in 1960. This publication discusses various forms of tarry beach deposits and reports the general location of 20 offshore oil seeps in Southern

California. In the University of Southern California studies, Merz (1) discussed physical differences in beach tar deposits. The present study presents a classification pattern.

Classification Scheme

The various oily substances encountered on the beaches were separated into six groups, selected on the basis of their presumed origins, and the six

SUNSET BEACH, STATION 1A - 1B

TORRANCE COUNTY BEACH, STATION 2

MUSSEL SHOALS, STATION 3

SUMMERLAND BEACH, STATION 4

COAL OIL POINT, STATION 5

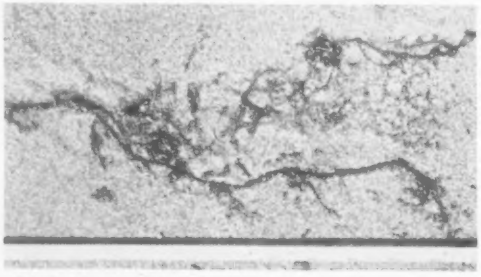
GAVIOTA BEACH, STATION 6

FIGURE 2.—Coastal sampling stations, 1959–60.

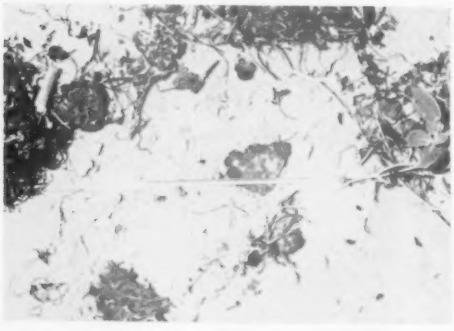
Rock-Like Pebble Tar Among Gravel Deposited at Mussel Shoals

"Fresh" Chunk of Tar Deposited on Cliff at Gaviota Beach

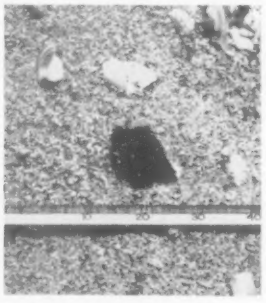
"Fresh" Chunk of Tar



Dendritic Pattern of Bead Drops of Tar at Summerland Beach



"Dried" Chunks of Tar on Coal Oil Point



Wafer Tar Deposit at Sunset Beach

FIGURE 3.—Typical tar deposits.

groups were subdivided into classes. The various groups and classes were established from physical characteristics which could be distinguished during field examination and verified by chemical and physical determinations in the laboratory. The individual groups and classes, some of which are illustrated in Figure 3, are defined as follows:

Group I.—This comprises particles deposited from offshore tar seeps, either directly or after one or more cycles of being deposited on the beach, refloated, and redeposited. The time of exposure of the particles on the beach ranges from zero for "very fresh" deposits to prolonged periods for "dried" deposits. The gross or apparent specific gravity of this tar is less than that of seawater due to entrained bubble cavities. The extracted tar (without cavities) is generally heavier than seawater. There are three distinct classes in this group.

1. Bead drops. Small spherical pieces of tar are deposited on the beach, usually in lines of bead-like segments, giving a lacework appearance. The beads are often mixed with seaweed. Individual tar pieces are small, from 1 mm to 1 cm in size and from 0.1 to 0.5 g in weight.

2. Wafers. These occur in sizes of 0.5 to 75 mm in diameter by 1 to 7.5 mm in thickness, and weight from less than 0.1 to 2.5 g. The wafers occur in the form of flat sheets, the thickness of each sheet being about one-tenth the maximum width of the wafer. The edges of the pieces are irregular in shape, giving the appearance of having been torn from a larger sheet of tar. The tar has a felted texture and occasionally contains small bubbles of entrapped gas. The wafers have a dull luster when first deposited on the beach but acquire the appearance of "fresh" tar when exposed to the sun. The wafers were observed to float in the surf, and were collected from all beaches sampled.

3. Chunks. These are discrete and sizable tar pieces, generally having a "melted down" appearance. They weigh from 0.5 g to several kilograms and measure in diameter from 1 to more than 30 cm. The pieces are thicker than wafers, ranging from 0.5 to about 4 cm. They adhere to rocks and other beach debris, and when exposed to the sun tend to "creep." A significant number of the chunks reach the shoreline in the form of globose masses. Some of the wafers may assume a similar globose appearance due to the heat of the sun, but the interior of such wafers are differentiated through their felted texture. Both have bubbles of entrapped gas. As distinguished from fresh chunks, which generally have a vitreous luster, the dried chunks appear dull and fracture rather than reform under stress.

Group II (Pebble Tar).—This comprises secondary deposits from offshore tar seeps, i.e., Group I materials which have been washed off the beach and redeposited, but which will not float due to accumulation of sand. The sand content varies from that amount which increases the specific gravity of the deposit to just above that of seawater (approximately 10-per cent sand) up to about 90-per cent sand.

The pebbles are smooth in appearance and are round or bean-shaped; they look like black pebbles. The pieces have a dull luster, and are worn round or globose in shape due to abrasion. The pebbles weigh between 0.5 and 100 g each, and have an apparent density between 1.06 and 2, depending on the sand content. This class of tar was collected from all beaches almost exclusively during the winter season. It is found in the vicinity of tidal pools and at the upper margin of beach gravel bars.

Group III.—This group includes all greasy substances released from ocean outfalls. Such deposits were found only at Sunset Beach; they had the appearance of brown stained wax or paraffin, and an odor characteristic of sewers. Their extracts contained 14-per cent ether insolubles and were 100-per cent saponifiable.

Group IV.—This comprises spills of refined petroleum products from tankers or other ships. The only specimen of this group collected during the

1959–60 investigation was a grease-covered wooden paddle found at Sunset Beach.

Group V.—This includes leakage or discharge from offshore wells and crude oil spills from tankers. Samples of this group were collected frequently in significant quantity from Summerland Beach, and occasionally in trace amounts at Sunset Beach, Mussel Shoals, and Coal Oil Point. The Summerland Beach material appeared to be seepage from an abandoned oil well in the nearshore water. The Group V deposits are divided into three classes:

1. Oil Film. These deposits cover extensive areas of the beach, generally concentrated in lines along the beach. The film tends to cover each sand grain and is best sampled by collection of the surface layer of sand.
2. Brown Foam. Occasionally the oil will be deposited as a brown foam along the water's edge.
3. Oil Patches. These are relatively infrequent and resemble oil poured on the beach. The oil patches are up to 3 or 4 cm in diameter by about 1 cm deep, usually located near the high water line.

Group VI.—This comprises all materials not included in the above five groups. The amounts of such materials collected were relatively insignificant and included oil shale, asphalt paving particles, and unidentified particles.

Genesis and Interaction of Beach Deposits

Based on field observations of the various phases of apparent deposition and redeposition cycles, and on laboratory analyses of specimens in progressive stages of alteration, a definite pattern appeared concerning the origin and changes in beach deposits. The tarry material originally coming from a marine seep is transported along the surface of the water due to entrained gas. This material is deposited on the beach and may be resuspended by the action of waves. Occasionally, and particularly during ebb tide, a piece of the tar is deposited beyond the reach of subsequent waves of that tidal cycle. The deposit is then softened by solar heat, loses volatile fractions, and collects sand. In subsequent tidal cycles this process is repeated until the deposit becomes either attached to permanent objects (such as rocks) or until it collects sufficient sand to prevent floating. The heavier or Group II deposits are moved along the coast and deposited on the beach generally together with gravel deposits. Eventually they are washed out to sea and are presumably deposited in submarine canyons, as indicated by the fact that small masses of tar are occasionally found in bottom cores at great depths.

Amounts of Oil-Tar Deposits

Most of the oil-tar materials found on Southern California beaches appear to be fresh (Group I) deposits of tars from offshore seeps. The geometric mean concentration of these deposits on most Southern California beaches is approximately 0.10 g/sq m, and the corresponding arithmetic average is approximately 0.13 g/sq m. These values are much less than those considered by Merz (1) to be a nuisance for beach recreational purposes. The amount of deposit at a given place fluctuates, as shown in Figure 4, with the peak values representing from 5 to 10 times the usual amount; hence the peaks are at or near the nuisance level. Such peak concentrations characteristically develop rapidly and then tend to disappear over the following one or two months.

Southern California beaches are rarely if ever entirely free of tar deposits and at least a few pieces of tar appear to be brought ashore with each tidal cycle. The Group I and Group II materials (those of natural origin) constitute the great bulk of oil-tar materials normally found on beaches,

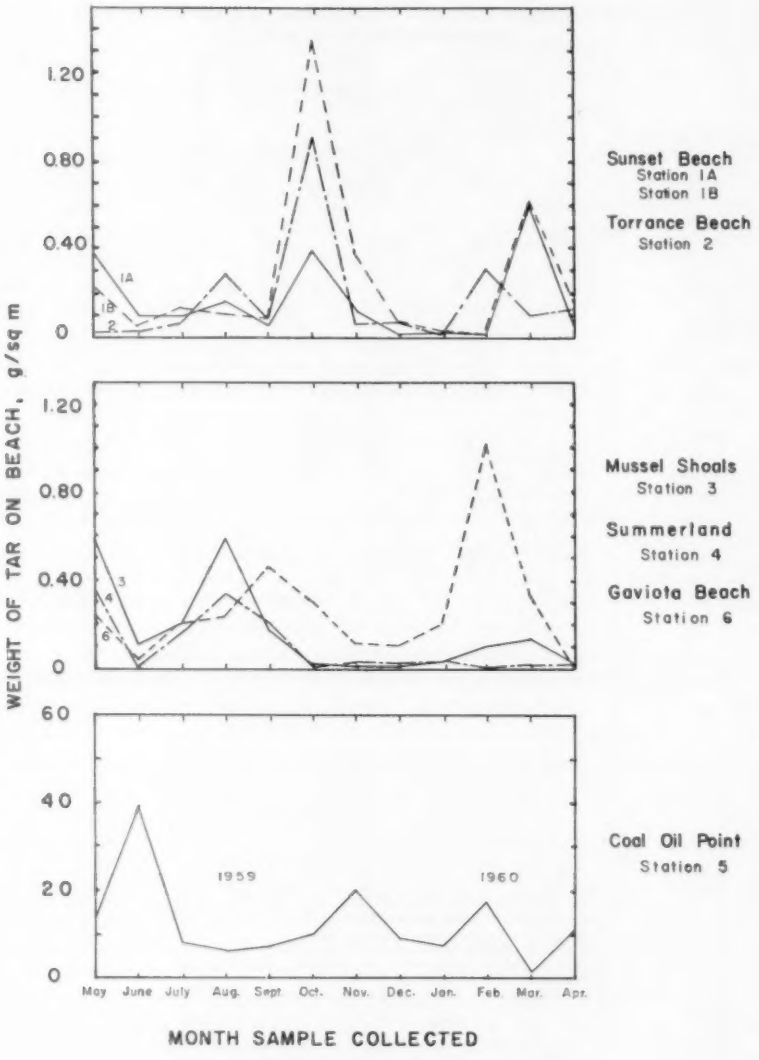


FIGURE 4.—Amount of tar collected.

and most of this is fresh (Group I) deposit. The amount of the Group I deposits follows a pattern characteristic of a given beach, which may be predicted on a statistical basis as will be discussed. The Group II deposits are closely associated with the amount of Group I material as well as the amount of deposited gravel; due to similarity between pebble tar and gravel as to size, shape, and density, both are transported onto the beach by the same type of surf currents. The Group I deposits are greater in the summer (when temperatures are warmer) and the Group II deposits are greater in the winter (when currents and wave action are stronger).

TABLE I.—Amounts of Group I Tar Deposited on Southern California Beaches in 1959–60 (g/sq m)

Month of Collection	Coastal Sampling Station and Station No.						
	Sunset Beach		Torrance County Beach	Mussel Shoals*	Summerland Beach†	Coal Oil Point*	Gaviota Beach
	1A	1B	2	3	4	5	6
1959							
May	0.307	0.204	0.021	0.598	0.378	1,150	0.244
June	0.096	0.054	0.035	0.101	0.002	3,890	0.035
July	0.097	0.139	0.074	0.198	0.159	842	0.200
Aug.	0.163	0.119	0.281	0.583	0.336	610	0.243
Sept.	0.055	0.099	0.091	0.181	0.207	754	0.462
Oct.	0.394	1.350	0.918	0.014	0.006	1,010	0.302
Nov.	0.126	0.385	0.063	0.003	0.016	2,010	0.119
Dec.	0.010	0.064	0.067	0.004	0.022	968	0.103
1960							
Jan.	0.023	0.029	0.006	0.035	0.030	426	0.202
Feb.	0.018	0.030	0.309	0.105	0.000	1,570	1.010
Mar.	0.600	0.626	0.107	0.134	0.004	122	0.346
Apr.	0.083	0.185	0.137	0.025	0.018	1,050	0.023
Geometric mean	0.090	0.143	0.088	0.059	0.024	9.20	0.180
Geometric standard deviation	4.18	4.42	4.39	8.50	11.4	2.26	3.17

* The pebble tars are not included in the amount of deposit at this station.

† The oil film deposits and the pebble tars are not included in the amount of deposit at this station.

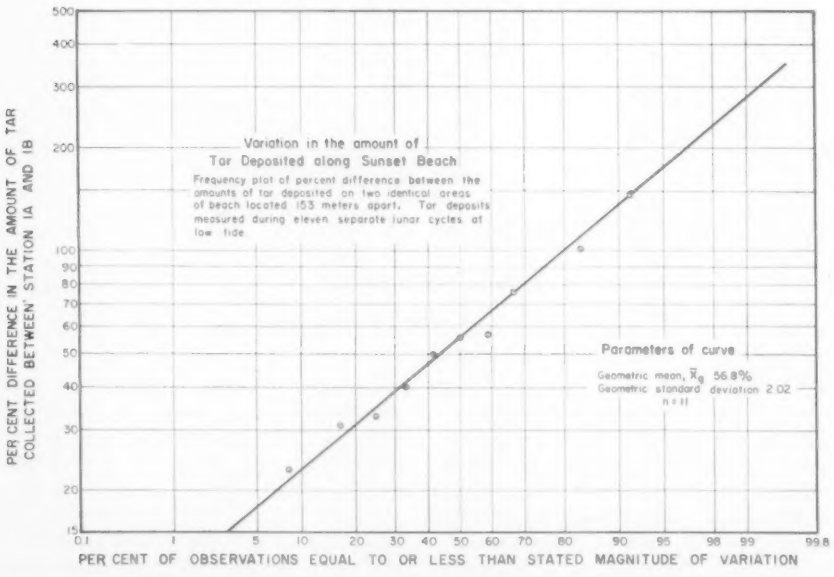


FIGURE 5.—Variation in the amount of tar deposited along Sunset Beach.

Group I Tar Deposits

Table I is a summary of the amounts of Group I tars found each month at the several sampling stations, which data have been plotted in Figure 4. There was generally good agreement between the amounts of oil-tars collected from the two nearby plots at Sunset Beach, as shown by Figure 5. The geometric mean deposits were 0.090 and 0.143 g/sq m for Stations 1A and 1B, respectively, and the corresponding geometric standard deviations were 4.18 and 4.42. Also, considering all stations, the amount of deposition was generally greater with closer proximity to offshore seeps, and the greater the deposition the less the variability in deposition.

The frequencies at which various amounts of tar were found at the six beaches were computed and plotted; for example, Figure 6 shows these frequencies for Sunset Beach and Torrance County Beach. From these data the geometric mean, $\bar{x}g$, and the geometric standard deviation, σg, were computed. At Sunset Beach, for example, 50 per cent of the tar deposits (σg) were less than 0.09 g/sq m, and 2.3 per cent (2 σg) were greater than 1.56 g/sq m.

Except for Coal Oil Point, there appears to be a correlation in the amount of tar deposited on the beaches between Point Conception and Ventura as shown in Figure 3 (Stations 3, 4, and 6). There is a similar correlation in deposits along Santa Monica Bay and San Pedro Bay (Stations 1A, 1B, and 2). The tar deposits along the coast between Point Conception and Santa Barbara (represented by Station 6) are greater than the deposits along Torrance County Beach and Sunset Beach (represented by Stations 1A, 1B, and 2), and the deposits between Santa Barbara and Ventura (represented by Stations 3 and 4) are less than those at Torrance County Beach and Sunset Beach.

Seasonal Effects on Tar Deposits

The deposition of tar along the Southern California coast appears to be seasonal. Although the data accumulated during the one year of sampling were insufficient to establish definite cycles, data shown in Figure 7 suggest that cycles exist. As shown in Figure 4, heavy deposits of tar periodically occur over extended areas of the coast. By grouping the data from all sampling stations (excepting Coal Oil Point) into three-month intervals corresponding with the seasons, a yearly cycle in the amount of tar deposited becomes more evident. The Group I tar deposits are heaviest in the fall and at a minimum in the spring, and are heavier during summer than winter. There also appears to be a correlation between seasonal changes in tar deposits and the temperature of the ocean surface water.

Chloroform Extractables on Sand

The amount of oil-tar residue in the surface layer of apparently clean beach sand was determined for the six stations during the month of February 1960. The average amount of film material was, surprisingly, 0.084 g/sq m or about one-third the arithmetic average amount, 0.220 g/sq m for the Group I tars collected from the surface of all beaches (excepting Coal Oil Point) during the same month. These data indicate that apparently clean sand contains appreciable amounts of oil-tar, but this is well distributed and not visible.

Chemical Characterization of Oil-Tar Materials

The chemical characteristics of the oil-tar samples, collected over the 12-month study period, were determined using a procedure patterned after the method given by Rosen *et al.* (4) as illustrated in Figure 8. Essentially this procedure involves extracting the oil-tar materials using chloroform as

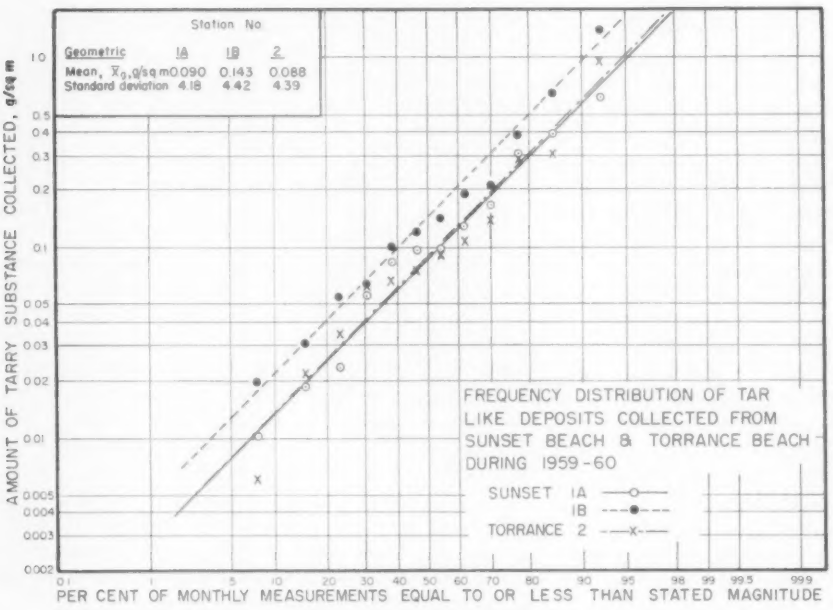

Station No
Geometric 1A 1B 2
Mean, $\bar{X}_g$, g/sq m 0.090 0.143 0.088
Standard deviation 4.18 4.42 4.39
AMOUNT OF TARRY SUBSTANCE COLLECTED, g/sq m
FREQUENCY DISTRIBUTION OF TAR LIKE DEPOSITS COLLECTED FROM SUNSET BEACH & TORRANCE BEACH DURING 1959-60
SUNSET 1A
1B
TORRANCE 2
PER CENT OF MONTHLY MEASUREMENTS EQUAL TO OR LESS THAN STATED MAGNITUDE

FIGURE 6.—Frequency distribution of tar-like deposits from two beaches.

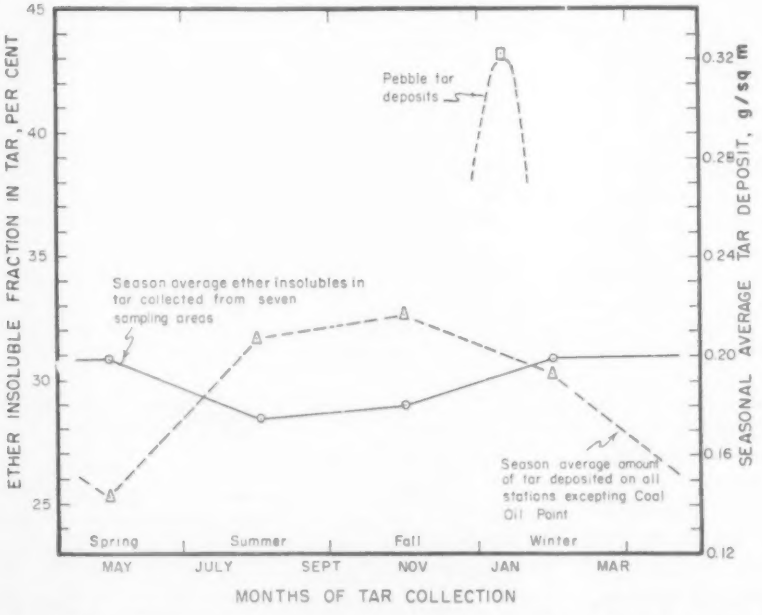


FIGURE 7.—Seasonal changes of the chemical character of tar deposits compared with seasonal changes in the amount and class of tar deposits.

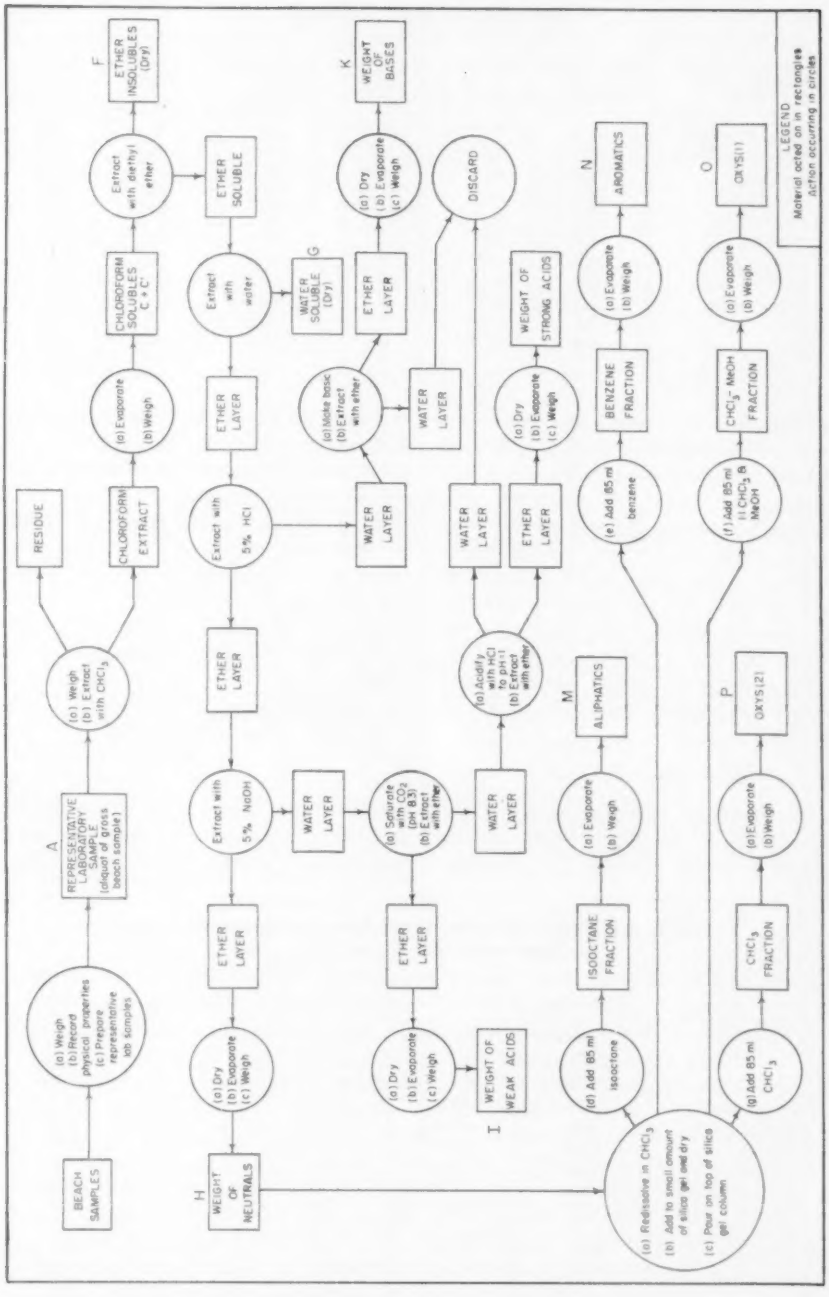


FIGURE 8.—Flow sheet for the analysis of oily substances.

TABLE II.—Chemical Characteristics of Typical Group I Beach Deposits Collected in 1959–60 (per cent)

Fractions Separated from Chloroform Extract	Sunset Beach Sta. 1A Sept. 59	Torrance Sta. 2 May 59	Mussel Shoals Sta. 3 Oct. 59	Summerland Sta. 4 Aug. 59	Coal Oil Point Sta. 5 June 59	Gaviota Sta. 6 Nov. 59
Ether insolubles	31.4	31.9	30.3	29.2	30.3	29.7
Water solubles	0.1	nil	nil	0.4	0.2	0.5
Neutrals	64.8	65.1	68.0	62.5	67.0	68.6
Aliphatics	14.4	17.7	10.2	13.5	25.1	19.9
Aromatics	31.1	32.1	34.1	27.0	20.3	29.5
Oxys I	14.3	12.7	15.7	16.6	18.7	17.1
Oxys II	4.5	1.5	3.4	5.4	1.2	2.1
Weak acids	0.4	trace	0.7	1.2	nil	0.1
Strong acids	0.2	trace	0.2	trace	nil	0.2
Bases	1.1	trace	0.5	0.2	nil	0.2
Loss	2.0	2.9	0.4	6.6	2.5	0.8

the solvent, followed by successive steps which separate the extract into various fractions comprising ether solubles, water solubles, neutrals, aliphatics, aromatics, oxygen, weak acids, strong acids, and bases. In addition to the routine samples (1 from each of 7 stations for 12 months, totaling 84), similar assays were made for six crude oils from various parts of the world and for six crude oils from offshore wells located along the Southern California coast.

Typical Beach Deposits

The chemical characteristics of six beach tars of the type which occurs most frequently (Group I), of three examples of beach tars that occur less frequently, of an unidentified oily deposit, and of a crude oil beach deposit are presented in Tables II and III. The six beach tar samples were selected on the basis of their ether insoluble fraction being close to 30 per cent, the most probable value for this fraction for all the beach samples collected during the 1956–60 investigation. It is evident from Table II that the chemical characteristics of the Group I tar composites from all beaches tend to have similar characteristics; hence these data cannot be correlated with specific seeps. Since the beach samples undoubtedly contained tars from several seeps, it cannot be concluded from

TABLE III.—Chemical Characteristics of Other Typical Beach Deposits Collected in 1959–60 (per cent)

Fractions Separated from Chloroform Extract	Pebble Tar	Dried Tar	Fresh Tar	Unidentified	Oil Film
	Summerland Sta. 4 Feb. 60	Mussel Shoals Sta. 3 Dec. 59	Mussel Shoals Sta. 3 Aug. 59	Sunset Beach Sta. 1A Apr. 60	Summerland Sta. 4 Jan. 60
Ether insolubles	38.2	43.6	26.2	32.6	6.5
Water solubles	nil	0.2	0.1	0.2	0.2
Neutrals	57.5	53.3	70.7	60.7	81.6
Aliphatics	12.7	5.6	14.5	30.7	21.7
Aromatics	28.3	22.4	27.9	14.7	38.7
Oxys I	14.7	21.8	17.3	8.4	18.6
Oxys II	1.8	2.3	5.1	2.3	2.2
Weak acids	0.1	0.1	0.1	0.1	0.1
Strong acids	0.1	0.1	0.1	0.1	0.1
Bases	0.1	nil	0.1	0.7	0.2
Loss	4.0	2.8	2.6	5.5	11.5

TABLE IV.—Comparison of the Chemical Characteristics of Crude Oils with Southern California Beach Tars *

Fractions Separated from Chloroform Extract	Values for 12 Crudes Assayed by Engineering-Science, Inc.			Values for 7 Crudes Assayed by Rosen *et al.* (Ref. 4)			Values for 79 Typical Beach Tars		
	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
Ether insoluble	15.5	nil	7.9	9.4	2.9	6.0	43.6	21.7	30.2
Water soluble	0.8	nil	0.1	<1.0	nil	<1.0	0.6	nil	0.2†
Neutrals	99.4	79.3	89.2	92.8	81.4	88.8	76.9	53.3	65.6
Aliphatics	45.4	12.4	28.9	38.0	18.1	26.9	29.1	3.7	14.1
Aromatics	52.0	27.4	40.3	44.0	25.6	35.2	38.2	19.5	29.3
Oxys I	21.9	9.8	14.3	23.9	4.1	14.5	27.2	11.6	16.5
Oxys II	6.7	1.4	3.3	2.7	0	1.0	13.4	0.9	3.5
Aromatics + oxys I & II			57.9			50.7			49.3
Weak acids	1.8	nil	0.5	2.9	1.0	<1.0	1.6	nil	0.3†
Strong acids	1.0	nil	0.4	4.9	trace	<1.0	1.3	nil	0.2†
Bases	1.9	0.1	0.5	<1.0	trace	<1.0	1.1	nil	0.2†

* Table values are weight percentage of samples after evaporation to constant weight.
† Data from 41 samples.

the present study the extent to which different seep tars have different chemical characteristics.

Dried vs. Fresh Tars (Group I).—In December 1959 a single piece of "dried" tar was collected from Mussel Shoals. The tar chunk was attached to a log partially embedded in the sand, and probably was on this beach for several weeks. The analysis, shown in Table III, indicates that the ether soluble fraction (44 per cent) is higher for dried tar than for the over-all or composited beach deposits (30 per cent) which comprise mostly fresh tar. The tar collected from rocks at Gaviota Beach in December had a similar dried appearance and in chemical characteristics was almost identical to those of the December Mussel Shoals sample.

In August 1959 pieces of tar having the appearance of having been freshly deposited were collected immediately on being deposited on the beach at Mussel Shoals. This material had an ether insoluble content of 26.2 per cent, which was four percentage units less than most tar samples and 18 percentage units less for dried tar. As almost all beach samples include both fresh and dried tar specimens, it is reasonable to conclude that much or almost all of the variation in the ether insoluble fraction in tar deposits may be due to varying proportions of fresh and dried specimens in the samples.

Because of the importance of the ether insoluble fraction in the characterization of beach deposits, the variation in the amount of this fraction contained in the monthly routine beach samples was compared with other observed phenomena. These relationships tend to illustrate the over-all dynamics of tar deposition. Figure 6 compares a plot of the average seasonal tar deposits from all stations (excepting Coal Oil Point because of its relatively heavy deposits) with a plot of the average ether insolubles from all sampling stations. The slight increase in ether insoluble content during the fall and winter, when the amount of tar on the beach was high, is explained by the presence of a large amount of dried tar at some beaches and the presence of pebble tar at others.

Crude Oil Film.—The analyses of the crude oil deposited at Summerland from abandoned nearshore oil wells serve as an excellent example of the chemical characteristics of such material after exposure to seawater and deposition on the beach. The samples collected from Summerland are of particular significance as they simulate

crude oil from a tanker spill or leakage from an offshore oil well. A comparison of the analysis of the January sample collected from Summerland Beach with the beach tar analyses (Table II) indicates the clear-cut separation of crude oil from natural tar deposits.

Crude Oils Compared with Beach Tars

The range of values for the characteristic fractions of the crude oil samples is compared in Table IV with data for the seven crudes analyzed by Rosen *et al.* (4) and with the analyses for the beach deposits assayed in this study.

Table IV reveals that the beach tar extracts contain a greater amount of ether insoluble fraction than the crudes, viz., an average of 30.2 per cent by weight compared with an average of 7.9 per cent. The minimum value of this fraction for all typical beach tar samples was 21.7 per cent, and the maximum recovered from the 12 crude oils was 15.5 per cent. Considering the expected variation in values obtained in the analysis for this fraction, which is 3.7 per cent for a 99.9-per cent confidence level, the maximum value for the fraction in crude oils and the minimum value for the fraction in beach tars would be 16.5 and 20.3 per cent, respectively. Or, on the basis of the 12 crude oils assayed, in less than one assay in 10,000 would the ether insoluble fraction fail to indicate the correct origin of either a crude oil or a beach deposit of seep origin.

In general, the ether insoluble fraction plus the neutral fraction constitute between 95 and 99 per cent of the extracts from both the beach tars and the crudes. Since tars contain more ether insolubles than crude oils, the crudes contain a greater amount of neutral fraction; however, the data show that the ranges of values for the neutral fraction in beach tars and in crudes may slightly overlap and therefore this index is less valuable than the ether insolubles for differentiating purposes.

A summarized comparison of the characteristics of seep tars versus crudes is presented in Figure 9. The data accumulated from the analyses are consistent in showing that a single fraction of the material extracted by the method of Rosen *et al.* (4); namely, interrelated, the ether insoluble fraction, is in itself sufficient to differentiate beeween a seep tar deposit and a crude oil deposit. The neutral fraction (which is interrelated to the ether insolubles and which, together with the ether insolubles, makes up to 94 to 98 per cent of the chloroform extract) is similarly useful, in many cases, for distinguishing between crude oils and seep tars. There is appreciable overlapping of the ranges of values for the other eight constituents, viz., the water solubles, aliphatics, aromatics, oxys I, oxys II, weak acids, strong acids, and bases.

Special Investigations

Throughout the course of the study investigations were carried on for the purpose of developing characterization techniques that would either supplement or improve the method of Rosen *et al.* These investigations developed the following conclusions:

1. Chromatography and fluorescence are valuable tools for characterizing oil-tar materials beyond the limitations of the method of Rosen *et al.*, but the application of these techniques is too complex and costly for routine characterization work.

2. Limited analyses of the sulfur content of oil-tar materials indicate that this determination may be a valuable means for characterizing seep deposits as to the seep of origin.

3. Measurement of the nitrogen content of oil-tar materials does not appear to furnish sufficiently extra information (beyond that given by Rosen *et al.*) to merit the extra work in

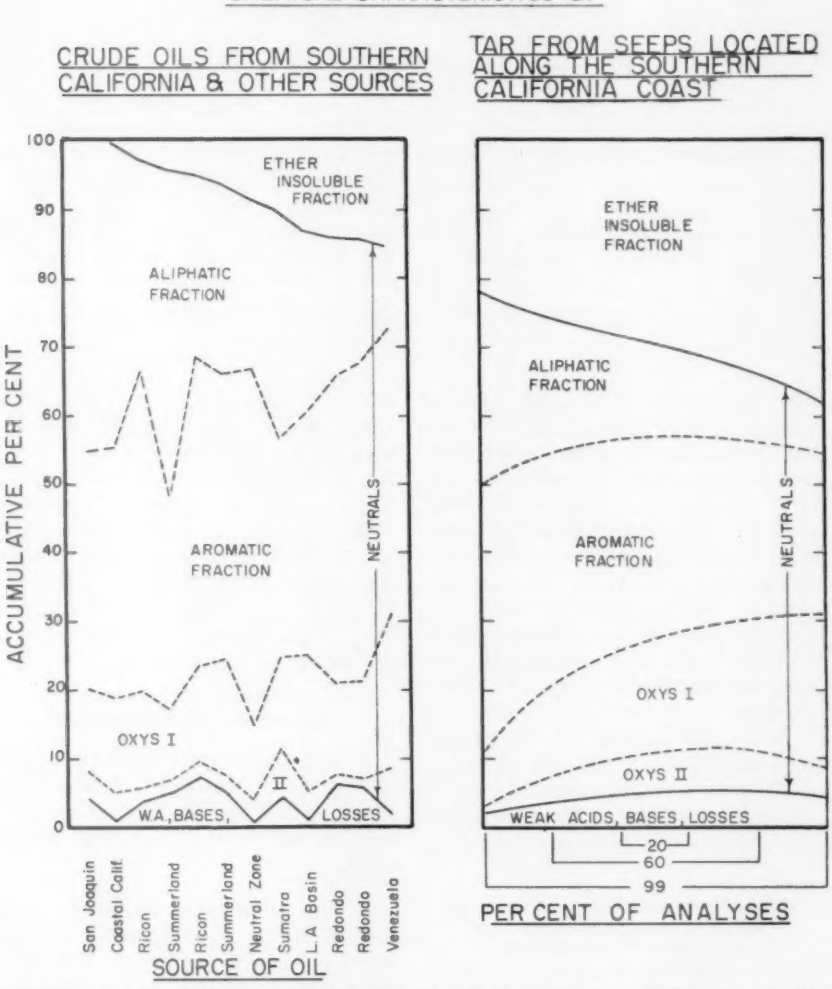


FIGURE 9.—Chemical characteristics of crude oils from Southern California and other sources and tar from seeps located along the Southern California coast.

making routine nitrogen determinations.

4. Determination of the specific gravity of the chloroform extract is a valuable index for supplementing the Rosen *et al.* method, as discussed below.

Specific Gravity

Specific gravity determinations were made of the chloroform extract for 42 of the beach tar samples (those collected during the last six months of the study) and, for comparison, for seven crude oil samples from offshore Southern California wells. Data for beach tar samples are contained in Table V and the crude oil comparison is given in Table VI. For the crude oils the specific gravity was determined for the original samples as well as the extract. The specific gravity of the extracts

TABLE V.—Specific Gravity of Tar Originating from the Southern California Coast (Determinations made at 20 ± 2°C)

Source of Tar	Month of Tar Collection, 1959–60						
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Avg
Sunset Beach	0.991	1.022	1.016	1.018	1.051	1.023	1.020
	0.976	1.059	1.020	0.968	1.033	1.031	1.015
Torrance	1.000	1.028	1.042	0.999	1.061	1.041	1.029
Mussel Shoals	1.031	1.062	1.041	1.034	1.077	1.051	1.049
Summerland	0.989	1.062	1.056	1.056	1.050	1.048	1.044
Coal Oil Point	0.996	1.042	1.027	1.029	1.071	1.042	1.035
Gaviota	1.033	1.041	1.041	1.023	1.061	1.051	1.042
Average	1.002	1.045	1.035	1.018	1.058	1.041	1.033

from the crudes was higher (by an average of 4.2 per cent) than for the raw crudes, due to loss of lighter fractions during evaporation of the chloroform following extraction. For the beach tars there was an apparent correlation between the extract specific gravity and the percentage of ether insolubles; this relationship might be expected since the asphaltenes which constitute much of the ether insolubles have densities in the range of 1.22 to 1.26 (5).

The specific gravity of the chloroform extract of seep tars was generally greater than one and averaged 1.0333; whereas for crude oils the extract specific gravity was generally less than one and averaged 0.941. Since the range of overlap is small, in many instances the extract specific gravity determination alone will differentiate between the two types of materials. This suggests that the specific gravity be the first measurement made following chloroform extraction, and that the Rosen *et al.* procedure then be followed only when there is still doubt as to the nature of the material.

TABLE VI.—Specific Gravity of Crude Oil Originating from the Southern California Coast (Determinations made at 20 ± 2°C)

Crude Oil from Offshore Wells	Raw Crude	Extract	% Increase
Rincon Oil Field			
State Well No. 43	0.912	0.954	4.6
No. 22	0.870	0.955	9.8
Summerland			
Low gravity	0.876	0.905	3.3
High gravity	0.826	0.898	8.7
Abandoned well	0.973	0.972	−0.1
Redondo			
No. 1	0.922	0.931	1.0
No. 11	0.955	0.971	1.7
Average	0.905	0.941	4.2

Summary and Conclusions

A program of quantitative sampling and chemical characterization of oil-tar materials on Southern California beaches led to the following conclusions:

1. The oil-tar material found on the beaches can be classified into six groups based primarily on physical characteristics distinguishable in the field but verified by chemical and physical determinations in the laboratory.

2. Quantitative sampling methodology, developed during the course of this investigation, indicates the geometric mean concentration of oil-tar materials on most Southern California beaches is approximately 0.10 g/sq m, which appears to be contributed primarily from offshore seeps.

3. Routine sampling and analysis of oil-tar materials permits a satisfactory statistical description of the amount of

oil-tar material expected on the beaches investigated at any confidence limit.

4. Deposition of oil-tar material on the beaches appears to follow somewhat of a seasonal pattern.

5. The amount of oil-tar residue (chloroform soluble) found on the surface layer of apparently clean beach sand amounts to about one-third of the arithmetic average amount of the total oil-tar particulate material found on the beach.

6. Chemical characterization of the oil-tar material found on the beaches using the method of Rosen *et al.* (4) in general permits definite identification of crude oil from natural or seep tar deposits. This is reflected primarily by a greater amount of ether insoluble material in the beach tar extracts compared to the crudes, viz., an average of 30.2 per cent versus an average of 7.9 per cent for the crudes.

7. Specific gravity determinations of the chloroform extract indicates that it may be possible to identify seep-tar material from crudes, inasmuch as the average seep tar extract specific gravity was 1.033 compared to 0.941 for the crude oil extract. To determine which of the above sources is the origin of the material it appears that the specific gravity determination should be made first on the chloroform extract, and that the Rosen *et al.* procedure then be followed only when there is still doubt as to the nature of the material.

Acknowledgments

The study program in 1957 was initiated by the Western Oil and Gas Association together with the California State Water Pollution Control Board. It was carried out by the University of Southern California with the collaboration of the U. S. Public Health Service.

The 1959 program was sponsored by the Western Oil and Gas Association.

References

1. Merz, R. C., "Determination of the Quantity of Oily Substances on Beaches and in Nearshore Waters." Sanitary Engr. Research Lab., Univ. Southern California (Oct. 1958).
2. Engineering-Science, Inc., "Analytical Characterization of Oily Substances Found on Southern California Beaches." Prepared for Western Oil and Gas Assn., Los Angeles, Calif. (July 1960).
3. Emery, K. O., "The Sea Off Southern California." John Wiley & Sons, Inc., New York (1960).
4. Rosen, A. A., Muserave, L. R., and Lichtenberg, J. J., "Pollution of California Beaches by Oil and Grease." Progress Rept. 1 and 2, U. S. Public Health Service, Robert A. Taft Sanitary Engr. Center, Cincinnati, Ohio (1958).
5. Witherspoon, P. A., "Studies on Petroleum with the Ultracentrifuge." Report of Investigation 206, Illinois State Geological Survey, Springfield, Ill. (1958).

SEE PAGE 1211 FOR A TIMELY REMINDER

INDUSTRY–ORSANCO COOPERATION IN POLLUTION CONTROL

R. S. Rhodes, O. C. Thompson, and N. J. Ehlers

The Ohio River Basin has been the scene of a unique demonstration of democracy in action. The story actually began a long time ago—1908. It was in this year that one of the north-central states declared that its river cities need not install sewage treatment facilities until communities in other states on the banks of the Ohio River did likewise. This initiated discussion among the several Ohio River states pointing to the desirability of joint action on pollution abatement measures.

However, no steps of consequence toward cooperation were taken until 1928. By then, increasing pollution had seriously burdened the river. This led to an informal agreement among the states of Pennsylvania, Ohio, West Virginia, Kentucky, New York, Illinois, Maryland, Indiana, Tennessee, North Carolina, and Virginia to act in concert for control of taste-producing discharges from industry.

Then came the droughts of 1930 and 1934. With them came the publicity that focused widespread attention on the difficulties of producing high quality drinking water from Ohio River sources in which the effect of pollution had been accentuated due to low flow. An aroused Cincinnati Chamber of Commerce alerted other civic organizations to join forces with sanitation authorities in a campaign for action on pollution abatement.

Formation of Compact

Important progress was registered when the 74th Congress of the United States, in June 1936, authorized the 14 states in the Ohio River drainage basin to enter into a compact for united action. Figure 1 illustrates the magnitude of the land area covered by the basin.

In 1938 delegates from 8 of the 14 states reached agreement on the form and type of Compact that could be recommended for adoption. By 1940 enabling legislation for this purpose had been adopted by Indiana, West Virginia, Ohio, New York, Illinois, and Kentucky. In June 1940 the 76th United States Congress approved the draft of the Compact on which the negotiating commission had agreed. Before it could become effective, however, reservations requiring participation by Pennsylvania and Virginia had to be satisfied. Preoccupation with the war effort delayed this step. It was not until April 1945 that Pennsylvania adopted the Compact, and Virginia became a signatory in March 1948. Ninety days later, in accord with the legal requirements, the Compact became a reality at a ceremonial signing on June 30, 1948, in Cincinnati, Ohio. Thus ended the first part of this cooperative action—eight sovereign states reconciling their views and reaching

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This paper was presented at the 33rd Annual Meeting of the Water Pollution Control Federation in Philadelphia, Pa., Oct. 2–6, 1960.

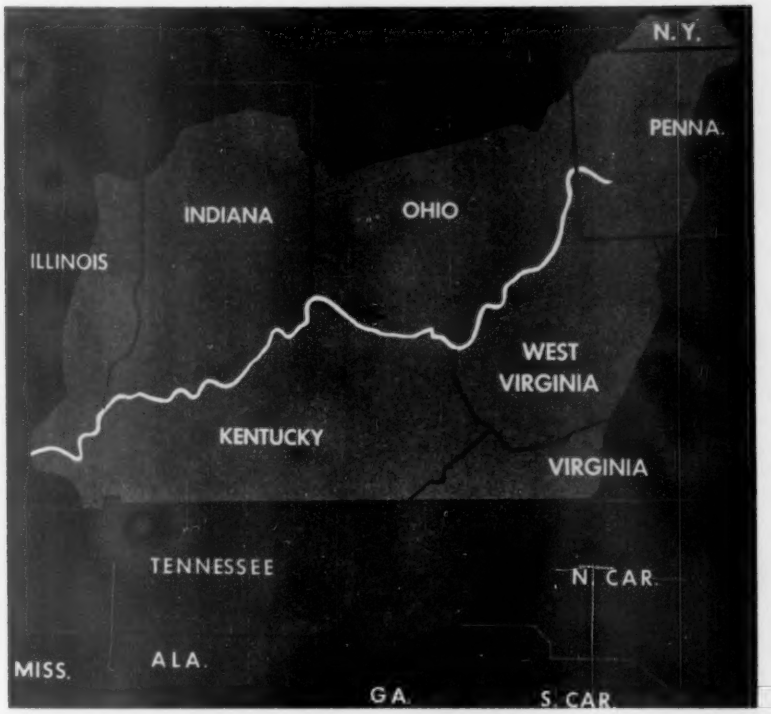

FIGURE 1.—Map of Ohio River Basin.

common agreement to take on a job that none could do alone.

Industry as Advisors

The official transcript of the document which established the Ohio River Valley Water Sanitation Commission contains no clue to the second element of this unique and dramatic demonstration of democracy in action. In the first year of the Compact the Commissioners and the staff addressed themselves to setting up an organization to implement the intent of the Compact. It was in the second year of the Compact that the Commission and its staff conceived a bold experiment in solving the complex problems of pollution control. This was the enlistment of industry groups in advising and assisting the Commission in solving pollution abatement problems and the establishment of rules, regulations, and standards under which these same industry groups could continue to exist in a profit-motivated free enterprise system.

Representatives of industry by generic groups were invited to meet with the Executive Committee of the Commission for exploratory conferences. The purpose of these conferences was threefold: (*a*) to acquaint industry at top level with the objectives of the Compact and the Commission; (*b*) to learn at first hand from industrial management the problems it faces in meeting pollution abatement requirements, what has already been done to comply with existing requirements, and what is proposed; and (*c*) to determine how the industrial group and the Commission might integrate their efforts.

Commission Organization and Relation of Industry

The organization chart of the Commission and the relationship of industry groups are evident from Figure 2.

On February 11, 1954, two original industry committees, the Organic Chemical Committee and the Chemical Brine Industry Committee, were consolidated into the Chemical Industry Committee in order to best serve the interests of the Commission and the chemical industry as a whole.

The Third Annual Report of the Ohio River Valley Water Sanitation Commission (1951) summarizes the basic functions of the "industry action

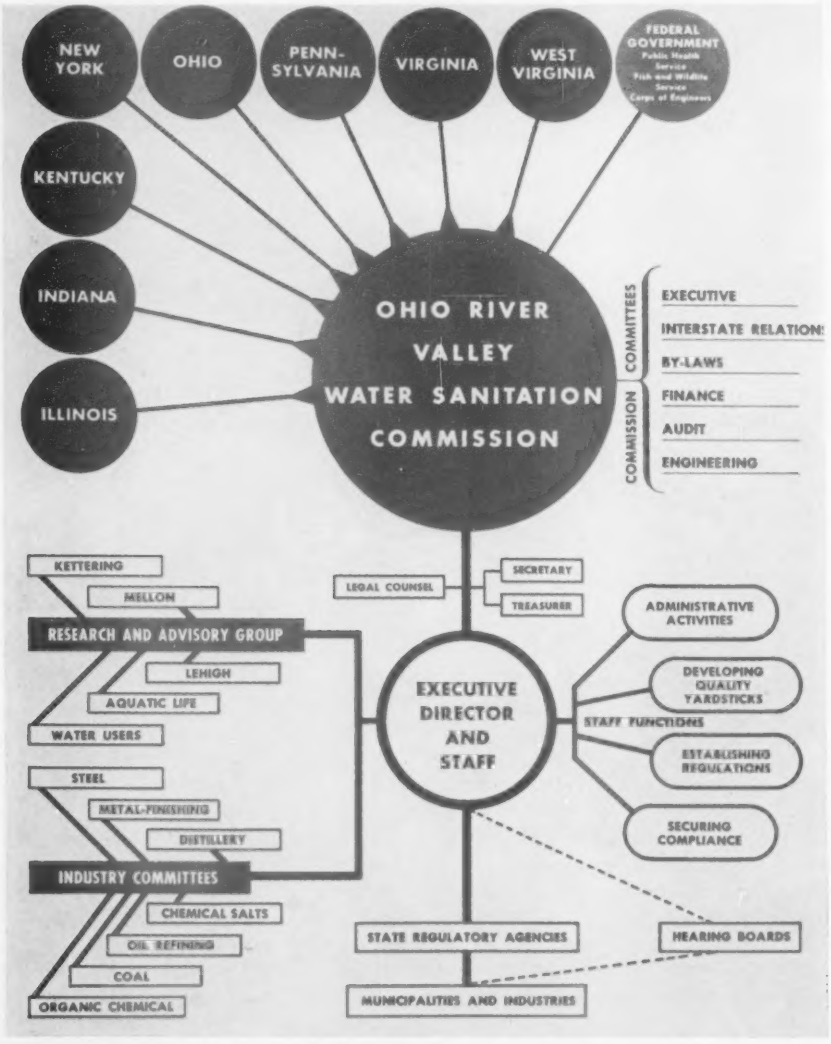

FIGURE 2.—ORSANCO organizational chart (1952). The Chemical Salts Committee and the Organic Chemical Committee are now the Chemical Industry Committee.

teams," as they were then referred to, as follows:

> To promote within the ranks of their specific industry an appreciation of the need to minimize pollutional wastes.
>
> To assemble facts and make an appraisal of the waste disposal problems of the industry, with specific reference to conditions in the Ohio River Valley.
>
> To consult with the Commission in the establishment of water-quality objectives and treatment requirements.
>
> To encourage joint research and development of more effective control of waste discharges through better housekeeping or by treatment measures.
>
> To maintain liaison through the Commission with other industry committees for the pooling of knowledge and the dissemination of information.

Nine years later (1960) these five statements still fairly accurately characterize the basic functions of the industry advisory committees.

Functions of Industry Committees

The industry committees are not expected to define what any company should be expected to do. The Commission preempts no relationships that exist or may develop between any one of its signatory states and the industry plants in that state. The organization, size, and work program of each committee are matters solely within the discretion of the industry group. Generally, the Commission staff has a member present at the industry committee meetings and, in addition, may have one or more Commissioners present. There is no established pattern of committee organization or activity. Each group has its own personality, reflecting industry characteristics and relationships, geographical or physical situations, and technical problems peculiar to certain manufacturing methods. Some of the committees have a formal organization and some do not.

Chemical Industry Committee

As an example of one of the more formal committees, the Chemical Industry Committee, after being formed from the consolidation of the original Organic and Inorganic Chemical Committees, drew up a set of bylaws in order to provide a sound foundation for its operation. These bylaws were finally approved by the combined committees in July 1954 and have been amended three times to date. The bylaws carefully outline the purpose of the Committee, its objectives, meeting schedules, requirements of membership, terms of officers, Commission liaison, Committee endorsement, and amendments to bylaws.

The objectives of the Chemical Industry Committee are as follows:

1. Work with the Ohio River Valley Water Sanitation Commission to place and maintain the interstate waters of the Ohio River Basin in a condition that will serve the public interests in the most beneficial and reasonable manner.

2. Assist in establishing reasonable water quality objectives in the Ohio River and its tributary streams.

3. Promote programs of education to inform owners, management, and operating personnel of all plants manufacturing or handling chemicals in the Ohio River Basin of the need for pollution abatement.

4. Promote cooperation of the chemical industry with the Commission, state, and other control agencies studying pollution in the Ohio River Basin.

5. Promote greater recognition of the importance of improved process engineering and equipment design as being essential in the abatement of pollution.

6. Promote the exchange of information on pollution abatement within the chemical industry by liaison with other industries, committees, technical societies, associations, regulatory agencies, and the Commission.

7. Define specific problems relating to pollution abatement in the chemical industry and assist in solving such problems.

Today the Chemical Industry Committee represents over 25 chemical companies in America. Since its inception in 1952, it has averaged four meetings a year, or a total of 34 meetings, many of which are held in the various capitals of the signatory states to make it convenient for the Commissioners of these states and local state authorities to meet with the Committee. It has brought about a better understanding of the mutual problems of the state control agencies on the one hand and industry on the other.

Changes to Meet Current Needs

It was not to be expected that a smooth working relationship of trouble-free cooperation between the industry committees and ORSANCO could be achieved overnight. In the first place, the Commission itself had not fully established its own operational pattern in the early years of its existence. This was a major experiment in the United States in basin-wide control of pollution which cut across many state boundaries. There was little precedent for this type approach and it was necessary to pioneer. The Commission, therefore, was eager to achieve success in making the Compact a working reality. The operation of the Commission, its Engineering Committee, its staff, and industrial groups is constantly under review and adjustment to meet changing conditions.

The concept of a regulatory agency actively seeking the cooperation and advice of the very industries it expected to regulate was a pioneering venture. Therefore, the method of handling this relationship is still being hammered out on the hard anvil of experience. It is a great tribute to the Commission, and especially its staff, that this cooperative and democratic venture is on a sounder footing today than it has ever been. It stands as a national example of one way of solving the communal problem of preserving public water in a usable condition.

The Chemical Industry Committee, in order to promote a mutual bond of confidence between the Commission and the Committee, has had an unvarying policy to hold no meetings closed to either the staff or the Commission. Without exception, members of one or the other, or both, have been present at every meeting that has been held. Thus, the Commission has had an opportunity to see and hear some of the acute problems and violent reactions that can and do arise in arriving at a nearly unanimous meeting of minds of some 25 fiercely competitive chemical corporations. A bond of mutual confidence has been established and has contributed greatly toward developing a sound working relationship between the Committee and the Commission. Working procedures will, of necessity, alter as the Commission itself changes its methods of operations.

The Commission extends its thank-you to industry committee chairmen with the Achievement Award shown in Figure 3.

Control Procedures

Perhaps one measure of the extent of the mutual confidence between ORSANCO and industry is indicated by the following: The Compact itself establishes basic requirements for the treatment of wastes and empowers the Commission to supplement these requirements; the Commission is empowered to prescribe and promulgate rules and regulations for the enforcement of treatment necessities; and, further, the Compact establishes the legal steps to be followed in establishing mandatory rules, regulations, and standards. Early in the operation of the Compact, it became evident that to follow the procedural steps required by the Compact would be an extremely lengthy and costly operation for each rule, regulation, and standard that was

FIGURE 3.—Sample of Achievement Award.

evolved. Therefore, the Commission adopted a policy of developing "control measures" which were then acted on by resolution at open Commission meetings after having been reviewed, at least in most cases, with industry advisory committees. Compliance with these control measures is then on a voluntary rather than a mandatory basis as far as the Compact is concerned. Of the some 14 actions, only 7 have been handled with the full procedural steps required by the Compact. These have primarily dealt with sanitary sew-

age in various sections of the Ohio River. The remaining actions which involve industry wastes have been acted on by the "control measure" basis. It is significant that industry in general has looked on these measures as requirements to be met even though compliance is legally on a voluntary basis.

Chemical Industry Committee Procedures

In view of the size of the Chemical Industry Committee it is necessary to execute much of the detailed work in subcommittees. These subcommittees consult with the Commission staff in their work. Progress reports are given by subcommittee chairmen at the parent committee meetings where they may or may not be discussed, depending on the subject at hand.

When a subcommittee has reached a conclusion, a recommending report is submitted. Where action between CIC and ORSANCO is involved, a two-thirds majority vote of those members present at a meeting is required.

Reports by CIC are generally submitted to the Commission staff. The staff then takes care of report distribution within the Commission. It is present practice for the full text of CIC reports to be made available to both the Commissioners and the Engineering Committee of the Commission.

On some issues, members of the CIC have made reports before the Engineering Committee, the full Commission, and ad hoc committees of the Commission.

The Commission staff keeps the industry advisory committees informed as to which pollutants are of interest or concern to ORSANCO and requests the industry committees to express their opinions. Ultimately, the staff prepares a report and may propose a rule, regulation, or standard covering control of a pollutant. In most instances, this is now referred by the Commission to all industry committees for their study and comment.

The Commission staff, and the Engineering Committee to an increasing extent, evaluate the industry comments and may or may not modify a proposed control before submitting it to the Commission for final action.

Industry committees do not always have an opportunity to comment on controls before the Commission takes final action. A case in point was the surprise action taken by the Commission in 1960 regarding a numerical interpretation of the term "significant discharge" used in chloride control.

The extent and range of the subjects treated by the CIC to date include: acidity and basicity, chlorides and fluorides, combined treatment of municipal and industrial wastes, detergents, design and operating practices, dissolved oxygen, fermentation wastes, information, iron and manganese, membership, methods of survey and analysis of water-borne wastes, oily materials, phenol—taste and odor, river transportation, site selection, stream flow regulation and low flow augmentation, stream quality objectives, temperature, total dissolved solids, toxicity, and water hardness.

Not all CIC work originates with suggestions from ORSANCO. Two examples of other projects are represented by the work of the Subcommittee on Design and Operating Practices, and Site Selection. The first group completed a brochure titled "Operating and Design Practices as Related to Pollution Control in the Chemical Industry." This has been circulated widely within the industry and was published in a national outlet. The second group issued a report, "Site Selection as Related to Pollution Control," which also was published.

The matter of pollution controls is a two-way street, and the CIC has suggested controls to the Commission which it felt would be beneficial. An example of this type of cooperation is

a Commission resolution on notification of spills and accidental discharges, which in concept was formally suggested to ORSANCO by the CIC. A second example involved a recommendation adopted by ORSANCO in which the Commission went on record with the congressional representatives of the eight Compact States that a portion of the capacity of future Federal dams should be dedicated to low flow augmentation and that sites be acquired now for future storage reservoirs.

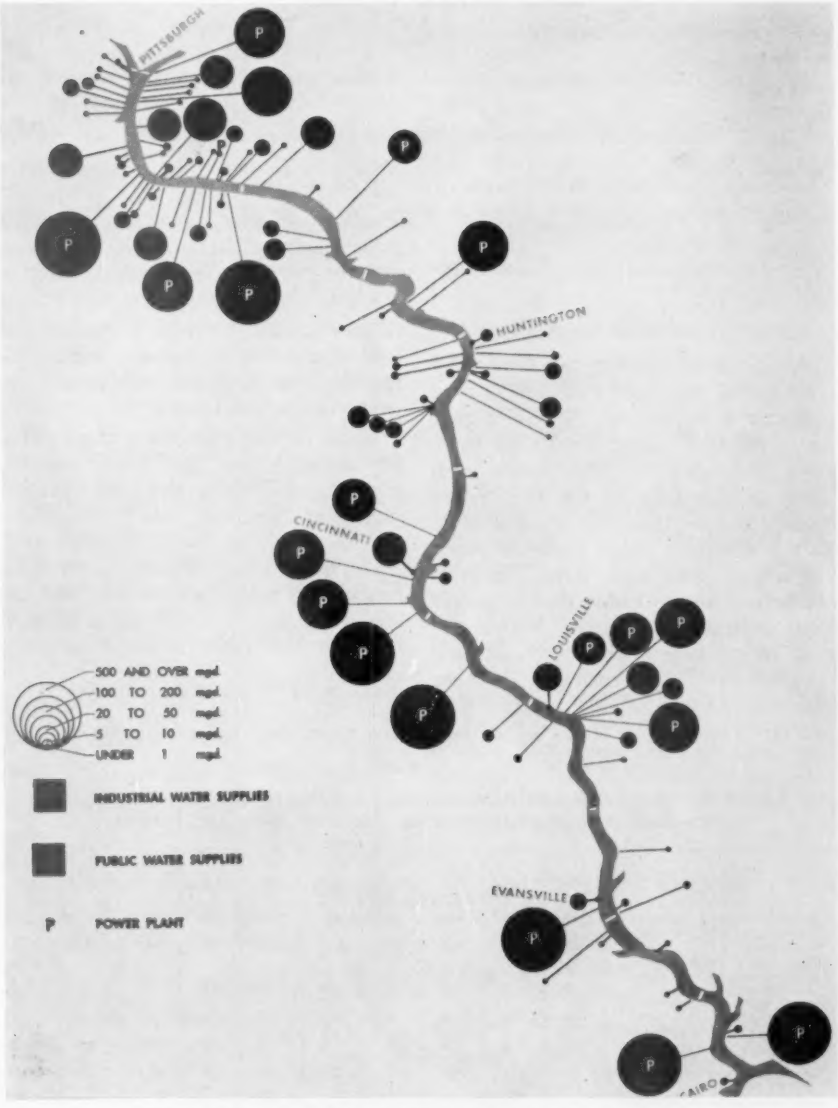

FIGURE 4.—Industrial activity in the Ohio Valley (1957).

TABLE I.—Status of Municipal and Institutional Facilities in the Ohio River Basin (July 1, 1959)

Status*	Ill.	Ind.	Ky.	N. Y.	Ohio	Pa.	Va.	W. Va.	Total	% of Total
Adequate treatment	41	117	125	6	209	81	25	25	629	39.3
	224,000	825,600	526,400	71,700	1,889,500	432,500	73,700	101,200	4,144,600	40.9
Treatment provided, but not adequate	4	17	13	7	32	12	27	11	123	7.7
	12,300	86,800	82,800	23,000	213,400	41,000	30,100	31,000	520,400	5.1
Treatment provided, not adequate; improvements under construction	3	6	1	0	8	3	0	2	23	1.4
	23,300	481,000	1,300	0	91,100	9,500	0	11,900	618,100	6.1
New treatment works under construction	1	8	4	1	33	86	3	18	154	9.6
	3,700	80,000	406,100	1,500	668,900	1,540,000	10,200	402,300	3,112,700	30.8
No treatment, construction not started	13	67	32	8	79	136	27	104	466	29.2
	39,600	174,500	86,300	15,300	341,000	609,300	51,400	200,600	1,518,000	15.0
Discharge of minor significance	3	62	23	0	82	12	6	16	204	12.8
	6,400	51,000	34,000	0	54,900	43,200	5,100	17,200	211,800	2.1
Total	65	277	198	22	443	330	88	176	1,599	100.0
	309,300	1,698,900	1,136,900	111,500	3,258,800	2,675,500	170,500	764,200	10,125,600	100.0

* Top figure opposite each item represents number of communities; bottom figure, population served.

Why Cooperation is Necessary

It might be well to consider why cooperation between ORSANCO and industry is important. Within recent times, the Ohio River Valley has come alive industrially. One hears such terms as the Ruhr of America, Atom Valley, and Voltage Valley. The Ohio Valley produces three times as much bituminous coal and three times as much steel as the Ruhr, the industrial heart of Western Europe. Within the past 13 yr, nearly $10 billion of new facilities have been constructed. These have created tens of thousands of new jobs and brought millions of dollars in new income. Figure 4 gives a picture concept of industrial activity on the Ohio River itself. Tributary operations are not shown.

Many factors have brought an influx of industry to the Ohio Basin—markets, materials, manpower, transportation facilities, and natural resources such as coal, oil, gas, salt, clays, and water. The last, water, is one of the important factors and the one which makes cooperation between industry and ORSANCO so very important.

Tables I and II show the status of municipal and industrial waste treat-

TABLE II.—Status of Industrial Waste Control Facilities for Industries Discharging Effluents Directly into Streams in the Ohio River Basin (July 1, 1959)

Status	Ill.	Ind.	Ky.	N. Y.	Ohio	Pa.	Va.	W. Va.	Total	% of Total
Adequate control facilities	9	173	119	16	256	144	19	181	917	63.5
Control provided, but not adequate	8	30	58	13	115	55	10	28	317	22.0
Control facilities inadequate, improvements under construction	0	0	11	0	19	3	0	1	34	2.4
New control facilities under construction	0	4	0	0	1	7	0	19	31	2.1
Planning stage, no action or not operating	0	4	13	18	0	59	8	42	144	10.0
Total number of industries	17	211	201	47	391	268	37	271	1,443	100.0
Complying with ORSANCO minimum requirements	17	180	137	16	344	244	28	185	1,151	79.8

ment on the Ohio River as reported by the Commission in 1959.

Summary

The fabulous expansion of the Ohio River Basin can be slowed and even stopped along some avenues by two alternatives now present:

1. Unrestricted pollution of the Basin water from many sources.
2. Excessive restrictive and mandatory control measures for the Basin water.

The common objective of both the Commission and industry is the middle-of-the-road path which lies between these two extremes. The achievement of this is a grave responsibility. It is a time-consuming process which has its foundations resting squarely on economics and science rather than political considerations. Many factors and facets of science are involved. Quick decisions and action cannot be taken because the future of the Basin could then be placed in jeopardy.

Because of the importance of the Ohio River Basin in America, all actions taken by the Commission will command national and international attention and tend to set the pace and pattern for other agencies dealing with control of water.

The following results can be at least partially attributed to the cooperative program worked out in the Ohio River Basin.

1. Rules, regulations, standards, and control measures which, by and large, are equitable and workable.
2. A progressively better understanding and respect of each other's problems by both industry and the control agency.
3. An improving working relationship between the control agency and industry.
4. Better quality of the water in the Ohio River in 1960 than in 1950 despite a vastly greater concentration of industry in the Basin.
5. An awakening on the part of industrial management to its responsibility in abating pollution in public waterways.
6. A recognition by industry, the Commission, and the Compact States of a single ultimate objective, "The maximum economic development of the Ohio River Basin through the maximum utilization of the Basin water with consideration and equity for all concerned."

This last objective cannot be taken lightly in the face of the explosive population increase of the world today. It is estimated that one out of every 20 humans born on this earth since the beginning of time is living today. It is vitally necessary that great river systems, such as the Ohio, be developed to accommodate the future population. The foundations laid today by the Commission and its advisory committees in the uses of the Basin waters will be the cornerstone for tomorrow's generations.

The Chemical Industry Committee considers the arrangement established by the Commission of asking the industries in the Basin their opinions and advice on matters pertaining to pollution as uniquely democratic. It is a system well worth preserving.

Acknowledgment

Photographs and tabular information have previously appeared in ORSANCO Annual Reports.

BUOYANCY OF AERATION TANK LIQUID

M. A. Kershaw

The Journal each year receives reports of drownings in aeration tanks of activated sludge plants. It also hears repeated comments or questions as to whether a person can remain afloat in a tank of liquid into which air is being diffused.

Some years ago this question became sufficiently important in England to attempt an experiment to answer this question. This article is adapted with permission from one entitled, "That Aeration Tank Danger Seems to be a Myth," published in the November 23, 1956, issue of *Municipal Engineering* (London).

There are many hazards and potential danger spots in a sewage works —such as the narrow walkways between tank units or around dosing chambers. In recent years a suggestion, believed to be from America, has been presented that the diffused air system of activated sludge presents additional hazards.

It has been said that the normal risk of falling into an aeration tank is increased since the liquid has lost its buoyancy because of air bubbles.

It is therefore argued that a body falling into an activated sludge tank would almost certainly sink to the bottom and remain there. The chances of rescue would then be remote.

Concern for Safety

A few years ago at a large activated sludge treatment plant in England the management was seriously concerned because of the danger to personnel falling into the aeration tanks, which, incidentally, were not protected by handrailing.

A note taken at a staff meeting at the works, dated December 17, 1953, records this discussion:

Walkways: It was agreed that warning notices should be issued that it was dangerous for men to take short cuts on the walkways between the aeration tanks and that it was forbidden to use such walkways except when absolutely necessary. It was also agreed that inquiries should be made regarding lifelines and grapples and that one of the first steps to be taken in the event of anyone falling into an aeration tank would be for the air supply to be cut off in order to restore the specific gravity.

Notice Issued

Arising from this meeting, the following notice was issued on January 16, 1954:

DANGER

Aeration channels—warning

The walkways between the aeration tanks must not be used unless it is necessary to do so in the course of duty. You are particularly warned to observe this instruction owing to the danger of falling into the tanks.

The presence of air bubbles in the tanks has the effect of changing the specific gravity of the liquid, and it is possible that even a strong swimmer, weighed down by his clothes and boots, would not be able to keep his head above water. Should a man happen to fall into these tanks, anyone witnessing it should immediately run to the air valve at the power house end of the tanks and turn it off. This will take the air bubbles out

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of the water and restore the normal bouyancy, giving a man a chance to rise to the surface.
Life belts and grappling irons on ropes are being provided.

Some time later, extensions to the aeration unit became necessary. During the construction of the new work, the contractors noted the above warning notices, which had been posted near the aeration tanks.

The posted warnings and other notices in the press caused sufficient interest to initiate tests to determine the validity of this viewpoint.

The newly constructed aeration unit on the new plant was offered for this investigation.

It was proposed to let men fall deliberately into an aeration tank when in full operation, the only difference being that the tank would contain water instead of the usual mixture of settled sewage and activated sludge.

In this particular unit, the air diffusers are of the dome type and are arranged for separate control of the volume of air to each quarter of the tank. The test was planned to operate in one section only, using air at the following volume rates of free air per square foot of aeration surface: 0.09, 0.22, 0.32, and 0.39 cfm.

The normal volume of air used in aeration tanks varies between 0.12 and 0.18 cfm per square foot of aeration surface.

FIGURE 1.—Swimmer entering aeration tank.

FIGURE 2.—Fully clothed swimmer in aeration tank.

Three Volunteers

Three members of the staff volunteered to test the buoyancy of the aerated water by jumping into the tank and attempting to swim when fully clothed and in trunks. Precautionary measures were taken which could be put into immediate effect if required.

The first man, clothed only in swimming trunks (Figure 1), dived into the unaerated water. Air was turned on while he trod the water, holding on to the access ladder at the same time. The object of this test was to obtain an idea of the immediate effect of the compressed air on the buoyancy of the water.

At this stage stringent precautions were in force, and the man was not allowed to release his hold on the access ladder. Throughout the test, however, he appeared to maintain his position easily and without any assistance from his light grasp of the ladder. Air volume was varied from 0.09 to 0.22 cfm per square foot.

The second man, fully clothed, complete with rubber boots and coat, then jumped in (Figure 2). Again as a precautionary measure, a lifeline was attached to his waist. Air volume was 0.22 cfm per square foot.

This man quickly surfaced, owing to the amount of air which was obviously trapped in his clothing, and he spent 6 to 8 min swimming and treading water in the aeration tank. At no time was the lifeline used to keep him afloat. The air volume was showing 0.32 cfm per square foot as a maximum during this test.

It was then thought sufficiently safe to make a further and more drastic test and the first volunteer, now fully clothed, plunged into the tank but without a lifeline.

He experienced no difficulty in swimming and remaining on the surface. The air volume was varied from 0.09 to 0.39 cfm per square foot.

During these experiments it was noted that the clothing of both men was partially inflated around the shoulders, although they were both wearing open-neck shirts. This suggests that air from the diffusers was actually being trapped in or between the layers of clothing worn.

At this stage those performing the test indicated satisfaction that there was no apparent increased risk due to the presence of compressed air passing into the water. No further experiments were therefore carried out with fully clothed swimmers.

The third man, however, in swimming trunks and wearing a face mask and flippers swam under the water in an attempt to observe the diffusion below the surface.

Owing to the light refraction caused by the bubbles, nothing but a thick fog was observed. Bubbles continued to flow over the glass of the face mask, no matter in which direction the swimmer moved. As a result, he experienced a complete loss of direction and position, and he was surprised to note that the lighter zone of the surface was to the side of his head and not above as anticipated.

Maneuvers

He also found that more effort was required to raise the rubber flippers above the aerated water than in still water, but the first swimmer (fully clothed) raised one boot two or three times above the surface without much additional effort.

To complete the experiments the second man swam from an aerated zone to an unaerated zone. This was easily achieved, but reversing the process, swimming from an unaerated into an aerated zone, was more difficult owing to the spiral flow effect between zones.

This swimmer stated that he experienced no apparent difference in the buoyancy of the two zones.

In the conduct of these experiments it should be noted that two of the volunteers were good swimmers, while the third had been a good swimmer some 16 yr before but had only swam on two occasions the year of the experiment.

It should also be remembered that these practical tests were carried out by people who knew beforehand exactly what they were to do. Any effect of shock caused by accidentally and suddenly falling into an aeration tank could not therefore be assessed.

Summary

It would appear that, provided a man can swim, even if only slightly in ordinary still water, he should be able to swim in a diffused air aeration tank; and in all probability the chances of survival for a non-swimmer falling into an aeration tank would tend to be increased by air collecting in his clothing.

SLUDGE DISPOSAL AT A PHILADELPHIA REFINERY

Robert G. Merman, Paul J. Ferrall, and George T. Foradori

The treatment of 13 mgd of wastewater by chemical coagulation and sedimentation at the Philadelphia refinery of The Atlantic Refining Co. produces 150,000 gpd of oil-bearing sludge. This material, together with 34,000 gpd of sludges from other waste control operations, is dewatered on vacuum precoat filters and the resulting filter cake is incinerated. Presented herein is a description of the sludge disposal facilities and an analysis of operating experience from the standpoint of equipment problems and operating costs. A plant-scale test to determine the effects of certain operating variables is described and an empirical relationship for filtration rate in terms of these variables is presented.

The location of the refinery * (Figure 1) in the City of Philadelphia, coupled with high value necessarily placed on ground space within refinery boundaries, dictate rather complete treatment of waste sludges. The sludge disposal facilities discussed in this paper are a part of Atlantic's north yard waste treatment plant (1) which was placed in operation in 1953. Currently charged to these facilities are sludges from the oil separator and chemical coagulation and sedimentation units at the north yard plant, and bottoms and residual emulsions from slop oil recovery plants in both north and south yards. In 1961, following completion of a coagulation and flotation plant (2) for south yard wastewater, an additional 30,000 gpd of sludge will be handled by this system.

* Atlantic Refinery.

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This paper was presented at the 33rd Annual Meeting of the Water Pollution Control Federation in Philadelphia, Pa., Oct. 2–6, 1960.

Description of Flow

A schematic flow diagram of the sludge disposal system is shown in Figure 2. Oil-bearing sludge produced in the flocculation and sedimentation units is pumped to a blending tank. At times, other sludges are blended with the flocculation sludge in this tank to improve dewatering characteristics. This tank serves also as a charge tank to the filters. A thickening tank receives degritted separator bottoms, slop oil bottoms, and residual slop oil emulsions. Free oil and water are drawn off intermittently.

From this tankage sludge is pumped to four rotary vacuum precoat filters. A slop oil filter handles the oily material from the thickener. This filter differs from the others in that it has a vapor hood and an insulated vat. The other filters operate on sludge from the blending tank. Filtrate from the slop oil filter is pumped to the slop oil recovery plant. Other filtrate is pumped to the sewer.

Filter cake from all of the filters is conveyed by belt to a rotary hearth incinerator. Although the cake usually contains sufficient oil to support its own combustion, one of four oil burners is continually fired as a safety precaution. Ash is transferred continuously from the incinerator to an ash storage tank from which it is inter-

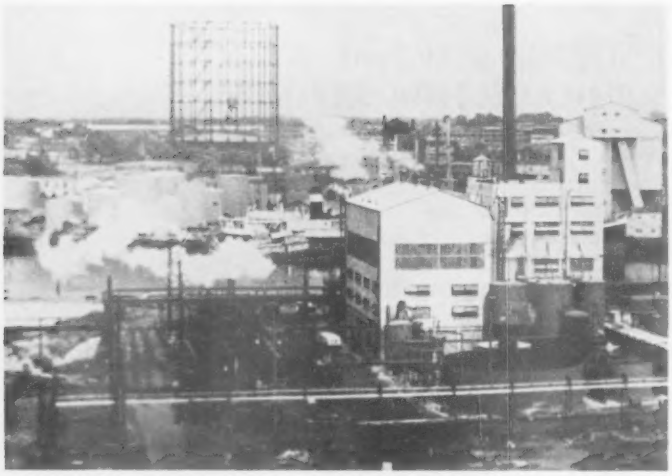

FIGURE 1.—Refinery location.

mittently loaded into trucks for disposal. To maintain continuous dewatering, filter cake is discharged into a storage bin during incinerator shutdowns. Combustion gas from the incinerator passes through a waste heat boiler generating steam for general plant and refinery use.

Equipment Details

With the exception of the precoating facilities, all major components of the sludge disposal system are represented on the flow diagram, Figure 2. All of the dewatering equipment is housed except the sludge tankage and the filter charge pumps. The housed equipment

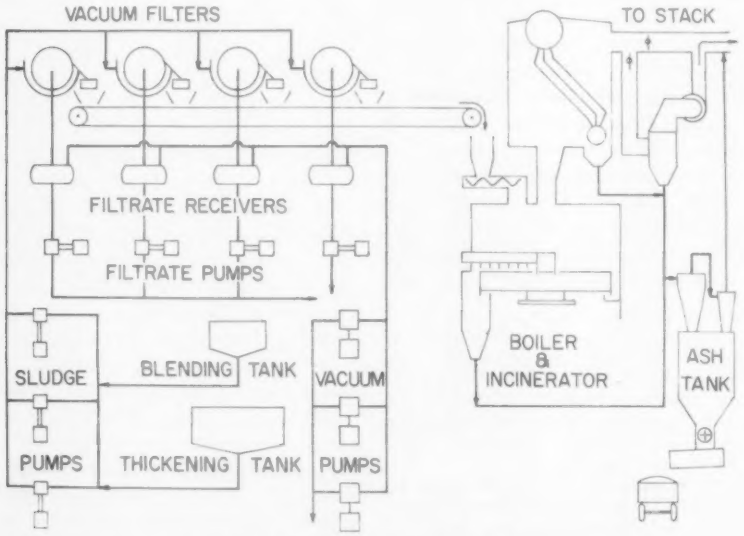

FIGURE 2.—Sludge disposal flow diagram.

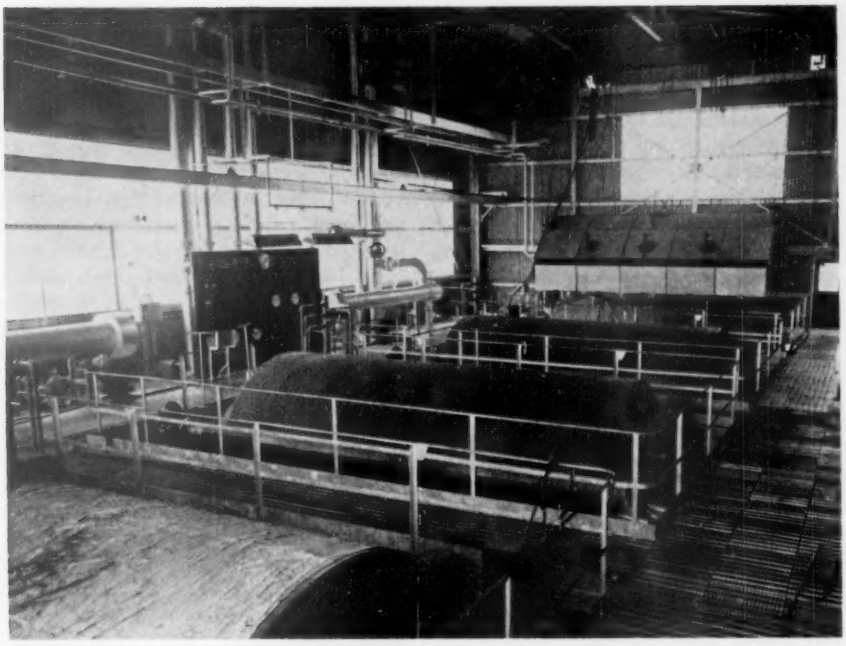

FIGURE 3.—Vacuum filters and control panel.

is arranged on four floor levels. The control board for the sludge system is on the upper level which is the main operating level (Figure 3). The vacuum pumps, filtrate pumps, and the precoat pumps, eductor, and filtrate receiver are located on the ground floor. Pertinent details on major parts of the system follow. Wherever possible, the original design basis has been included. However, in the 10 yr since these facilities were designed, significant changes in sludge quantity and characteristics have taken place. Therefore, there will be necessarily some discrepancies between design bases and current data.

Sludge Tankage

The blending tank was designed to provide 6 hr storage for the charge to the filters at average filtration rates. It is a closed tank, 20 ft in diam and 19 ft high and has a capacity of 44,500 gal. It is equipped with a picket fence type blending mechanism and a bottom collecting scraper. It has a small heating coil to maintain the contents above 50°F. Liquid level and temperature are indicated locally and on the control board. A high level in the tank sounds an alarm at the control board.

The thickener was designed to hold the maximum predicted volume of charge material. It is an open tank, 50 ft in diam and 18½ ft deep and has a capacity of 270,000 gal. It has a center inlet and a peripheral oil baffle and overflow launder. The oil baffle extends seven feet below the overflow level. A swing suction is provided for oil skimming and a bottom scraper mechanism for sludge collection.

Sludge Transfer Facilities

Three 340-gpm steam driven duplex reciprocating pumps are used to transfer sludge between tankage and to

charge the filters. These pumps were sized on the basis of a maximum expected filtration rate of 9 gph/sq ft. Reciprocating pumps were selected over centrifugals to minimize any adverse effects pumping might have on sludge filtration characteristics. Likewise, to minimize maintenance problems associated with sludge pumping, the pumps are equipped with ferrodur cylinder liners, stainless steel rods, darcova cups, and ball valves in side pots. When pumping to the filters, these pumps are automatically controlled by a pressure controller which maintains a predetermined pressure in the charge line by throttling the steam to the pump. Line pressure is indicated and adjusted at the control board.

Two six-inch charge lines are provided from the charge pumps to the filters. Each line contains a venturi section and flow is recorded at the control board. To prevent contamination of the differential meter, a small quantity of surge water is continually pumped into the venturi section through the instrument lines. A steam injection heater is provided in one of the charge lines. Precoat is pumped to the filters via a separate four-inch line.

Vacuum Filters

Pilot-plant studies conducted on a 0.5-sq ft rotary vacuum precoat filter indicated this method of dewatering to be the most satisfactory for the sludges expected. Centrifuging and spray drying were also considered. A laboratory study indicated that dewatered solids would not discharge satisfactorily from a centrifuge. Spray drying was eliminated from consideration on the basis of a plant-scale trial, which indicated an excessive loss of hydrocarbon and ash to the atmosphere. Filters were sized on the basis of the following pilot-plant filtration rates for predicted sludge quantities and concentrations:

Source of Sludge	Filtration Rate (gph/sq ft)
Flocculation sludge	3.6
Separator bottoms (excluding grit)	3.6
Slop oil bottoms	1.0
Slop oil emulsion	6.0

Four rotary vacuum precoat filters are used. Filter drums are 10 ft in diam by 18 ft long and are covered with 24 × 110 mesh stainless steel screen. Each drum has 560 sq ft of filtration area and is operated at about 45-per cent submergence. Drum speeds can be varied from 1 to 5 min per revolution. The knife advance mechanism is driven from the drum drive and can be varied in 12 steps from .00065 in. to .00715 in. per revolution of the drum. An oscillating rack of bars extending the length of the filter vat provides the agitation and is driven through a variable speed gear box. Sludge enters the vats at the side through three 6-in. diam baffled inlet lines. Liquid level in the vats is controlled by a float-positioned control valve in the charge line to each filter. The slop oil filter has a vapor hood and an insulated vat.

Vacuum System

Sizing of vacuum pumps and filtrate receivers was based on recommendations of the filter supplier. Three, single cylinder, double acting, single stage, 150-hp motor driven, reciprocating pumps are used, each having an effective displacement of 2,500 cfm at 2.5-psia suction pressure. To maintain precoat on the filters in the event of an emergency shutdown of the vacuum pumps, a steam eductor having a 1,600-cfm capacity at 12-psia suction pressure, is provided.

Each filter drains to a separate filtrate receiver, 6 ft in diam by 10 ft long. Vacuum is applied to each receiver through individual pipe loops extending 34 ft above the receivers to prevent the flow of filtrate into the vacuum pumps. These loops connect to two vacuum headers, one for filter-

ing and one for precoating. The two headers are inter-connected through a pressure control valve which prevents the vacuum in the filtering header from falling below a predetermined value, usually 15 in. Hg, during precoating. A knockout drum 5½ ft in diameter by 8 ft high and liquid accumulator 4 ft in diameter by 6 ft long are provided between the distribution headers and the vacuum pumps. In addition, each pump has a small moisture trap and liquid accumulator. A vapor condenser and liquid accumulator are provided on the slop oil filter between the receiver and the barometric loop. Vacuum line sizes vary from 8-in. diam for individual filters to 16-in. diam for lines serving four filters. Vacuum pump exhaust goes to the atmosphere via a water spray knockdown drum and mist eliminator.

Externally mounted liquid level controllers at each receiver control the steam to the filtrate pumps. Likewise, externally mounted high level alarms at each receiver cut off the vacuum pumps and sound an alarm at the control board. A high level controller in the knockout drum also cuts off the vacuum pumps. Similarly, a high level alarm in the accumulator serving the knockout drum sounds an alarm.

The vacuum system was originally constructed without the knockout drum and accumulator and without the accumulator following the vapor condenser. Likewise, liquid level control was provided only for the slop oil filtrate receiver. These omissions, coupled with internal high level alarm assemblies and excessive turbulence in the filtrate receivers from air entering through improperly operating valves in the filtrate pumps, resulted in costly damage to the vacuum pumps from water entering the pumps probably by entrainment and as condensate.

Precoat System

Dry precoat from a feed hopper is picked up by a water eductor and discharged to the filters as a 1-per cent slurry. The hopper is designed to hold 3,000 lb of diatomaceous earth, which is about 20 per cent in excess of that needed to precoat one filter. The hopper is filled by a manually loaded flight conveyor which has a capacity of 3,600 lb/hr. During precoating, the carrier water is pumped to the eductor from a 3,300-gal precoat surge tank by an 800-gpm centrifugal pump. Filtrate is recycled through the filter and receiver back to the surge tank.

Filter Cake Handling

Each filter has an endless belt which receives cake as it is cut and conveys it to the main conveyor belt which runs perpendicular to the filter belts and discharges into a hopper at the incinerator. All belts are 14 in. wide and constructed of 4-ply canvas duck covered with rubber. A sludge weighmeter weighs and totalizes the cake on the belt. A totalizer and rate recorder are mounted on the control board.

At times of incinerator shutdown, cake is diverted from the main belt to another belt discharging to a storage bin. The bin was sized to provide two days storage at average cake production rates. A clam shell bucket was furnished to return cake from the bin to the incinerator. The strong tendency of the cake to hang up in the incinerator feed hopper has made this return feature impractical.

Incineration Facilities

The incinerator, boiler, and ash handling equipment were purchased as a package to meet specifications based on expected filter cake quantities and characteristics and to meet the requirements of the City of Philadelphia air pollution ordinance relative to fly ash emission (Figure 4). The system was designed to handle 4.35 tons per day of filter cake having a heating value of 10,000 Btu/pound. The boiler is rated at 1,020 hp to produce 30,000 lb/hr of steam at 200 psi and 99 per

cent minimum quality. Ash handling equipment is designed to transfer ash to the storage tank at a minimum rate of 10 tons/hr and to unload the tank at a 50 ton/hr rate. The storage tank was designed to hold a three day production of ash.

The incinerator is circular and has a 25 ft diam rotating hearth. The combustion chamber is about 4 ft high. Filter cake is fed by a screw conveyor which moves it from a hopper at the end of the conveyor belt to an opening in the top of the furnace near the center. As the hearth revolves, the burning cake is rabbled and moved in a spiral path to an ash hopper at the periphery by four stationary rabble arms. The rabble arms extend radially from a center support out through the furnace wall and are spaced 90 degrees apart. Each arm contains six plows extending to within 1 to 2 inches of the hearth. The hearth can be rotated at three speeds, 0.3, 0.6, and 0.8 rpm. A sand seal is provided between the rotating hearth and stationary furnace wall. This consists of a steel skirt around the circumference of the hearth which extends into a steel trough filled with sand and supported from the furnace wall.

Primary combustion air is supplied by a 12,000 cfm blower through eight inlet ports spaced uniformly around the furnace wall. Additional air from a 1,000 cfm blower enters the furnace after cooling the rabble arm and plows via holes in the plows. Four oil burners are spaced 90 degrees apart around the furnace wall. Each burner is rated at 2,500,000 Btu/hr and burns #6 fuel oil. The hot combustion gases flow upward through a throat section at the center of the hearth and into the waste heat boiler situated above the incinerator. A 32,0000 cfm exhauster pulls the cooled gas from the boiler through a multiclone dust collector and discharges into a stack 150 ft high by 6

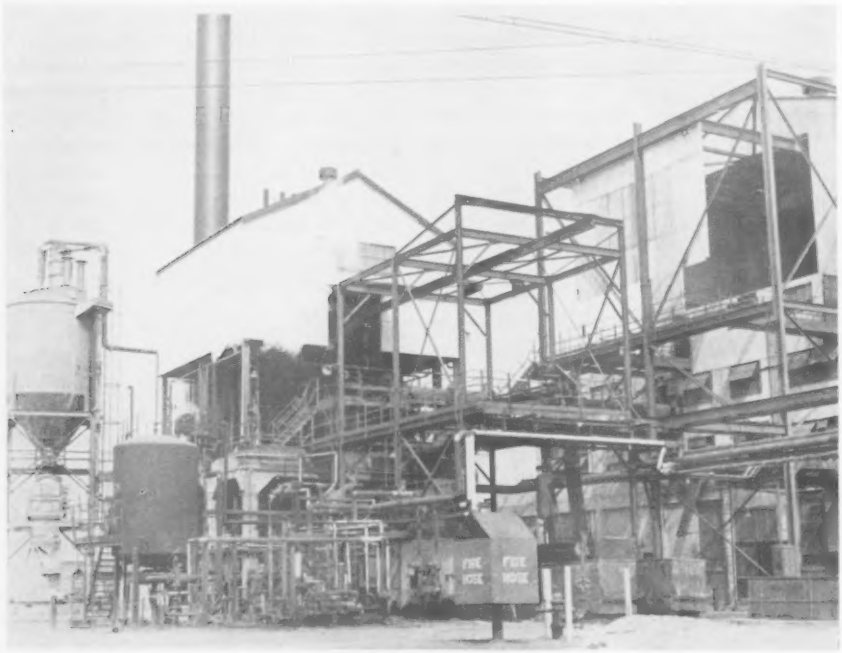

FIGURE 4.—Filter building.

TABLE I.—Quantity and Characteristics of Filter Charge and Filter Cake

Material	Filter Charge (gpd)	Solids (ton/day)	Solids (%)	Oil (%)	Water (%)	Ash (%)
Flocculation sludge	150,000	10.7	1–3	2–6	91–97	—
Separator bottoms, slop oil bottoms, slop oil emulsions	34,000	4.2	1–3	30–50	47–69	—
Filter cake	5,300*	77.5	21	27	52	15

* Btu/hr.

ft in diam. Ash is transferred from the incinerator hopper, the boiler hoppers, and the multiclone by a steam eductor which discharges ash to the storage tank through two cyclone separators and exhausts to the stack. Carrier air is drawn from the furnace. Ash is loaded into trucks from the storage tank by an unloader equipped with water sprays. Ash removal from the incinerator hopper is automatic and timer controlled.

A temperature control system regulates a damper in the primary air supply and the pressure of oil supplied to the burners to maintain a relatively constant temperature in the incinerator. A draft controller maintains a preset draft in the furnace at all times. Draft in the furnace and stack and pressure in the primary air supply ducts are indicated locally. Temperature in the furnace is recorded locally and indicated on the control board.

In practice operating temperatures are maintained above 1,400°F to prevent smoking and below 2,000°F to prevent clinkering. A smoke detector in the stack sounds an alarm at the control board.

The waste heat boiler and associated feed water appurtenances are of conventional design and have therefore been excluded from this discussion.

Operation

The sludge disposal facilities described above have been in operation as a unit since April 1954. The dewatering system began operation in December 1953. Current sludge quantities and characteristics are shown in Table I. A breakdown of operating costs based on operating data for 1957 to 59 inclusive, is shown in Table II. From this it can be seen that the disposal cost per ton of dry, oil-free solids is $24.9 net or $42.2 excluding steam credit from incineration. Of this total cost, 56 per cent is for dewatering and 44 per cent for incineration. Numerous efforts have been and are being made to reduce these costs. Maintenance and precoat costs account for over 50 per cent of the total and therefore have been the target for much of the cost reduction effort.

The high cost of maintenance reflects the short life of much of the system, due chiefly to the severe service and to faults in basic mechanical design of certain equipment. The vacuum system, i.e., pumps, filters and conveyor belts, and the incinerator-

TABLE II.—Cost Breakdown for Sludge Disposal

Item	Dewatering ($/day)	Incineration ($/day)	Total ($/day)	Dry Solids ($/ton)
Precoat	131	—	131	8.8
Power	52	12	64	4.2
Steam	8	16	24	1.6
Fuel	—	46	46	3.1
Boiler feedwater	—	24	24	1.6
Ash disposal	—	51	51	3.4
Maintenance	114	84	198	13.3
Labor	46	46	92	6.2
Cost	351	279	630	42.2
Steam produced	—	−258	−258	−17.3
Net cost	351	21	372	24.9
Dewatering	—	—	—	23.5
Incineration	—	—	—	1.4

boiler system each account for about 40 per cent of the maintenance dollars spent on the sludge disposal facilities. Vacuum pump maintenance has been largely in connection with excessive cylinder and piston wear and valve fouling. Cleaning of screen and vats and repairs to agitator drives and trunion glands represent major vacuum filter maintenance problems. The belt conveyors require almost constant surveillance to keep them aligned and clean, and to keep scrapers, guides, skirts, etc. functioning properly.

The incinerator has required extremely high maintenance. The rotating hearth and the stationary rabble arms account for much of the maintenance work. This has been in the nature of repairs to the insulation on the rabble arms, the insulating brick on the hearth, and the alignment of the hearth in respect to the rabble arms and the sides of the furnace. Original fire brick insulation on the rabble arms has been replaced with a plastic refractory which has shown better resistance to the shearing action of pieces of slag, broken brick, and other debris that occasionally become wedged between the arms and the hearth. Likewise, the outer 1½ feet of hearth brick have been replaced with a castable refractory anchored to the steel hearth plate. This outer ring has eliminated the gradual radial movement of the hearth brick toward the periphery and the eventual failure of the steel retaining angle which on occasion was pushed against the furnace wall stopping hearth rotation.

A circle of eight uniformly spaced rollers support the rotating hearth by means of a 3 foot 2½ in. diam track mounted on the underside of the hearth structure. This mechanism has replaced the original hearth bearing which was completely inaccessable for maintenance. This modification, made in 1956, has also proved to need much maintenance because of periodic alignment adjustments and eventual track repair necessitated by severe track wear.

The ash handling system has contributed significantly to incinerator maintenance requirements, and likewise to operating costs. Flap gates on the cyclones which discharge into the ash storage tank require frequent adjustment and repair to prevent the escape of ash to the stack via the steam exhauster which supplies vacuum to the ash conveying system. Likewise, very hard deposits of fine ash form in the eductor throat when the temperature in the system drops below the dew point of the gas. These deposits have resulted in frequent shutdowns of the ash system for cleaning during the winter months. Recent efforts to control the carrier gas temperature at around 200°F by withdrawing part of the gas from the furnace have reduced deposition considerably.

In order to prevent bridging and clinkering of ash in the incinerator hopper and to aid in maintaining carrier gas temperatures at the desired level, it has been necessary to operate the steam exhauster on a one minute cycle. This requires much more steam than is theoretically required for the amount of ash involved.

Precoat consumption is of course a function of filter operating time, knife cut, and cycle time. Until recently, no scientific effort has been made to optimize filtration conditions. Cycle time has averaged 3 min on the sludge filters and 5 min on the slop oil filter. Knife advance on the sludge filters has averaged .00125 in./rev (a No. 2 cut) and on the slop oil filter, .0029 in./cut (a No. 5 cut). Vacuum has been in the range 18 to 21 in. Hg. Recent test runs to establish optimum filtration conditions and potential filtration capacity are discussed below.

Several other promising approaches to cost reduction are being pursued. These include improvements to incinerator efficiency and utilization of ash as a precoat or a precoat extender, as

a weighting agent in the sedimentation operation, as a component of paving, and on fire banks to reduce erosion and weed growth.

Filter Rate Studies

In setting up the experimental filtration work we attempted to cover only those variables over which we had immediate control.

These were: vacuum, knife advance, and cycle speed.

Admittedly sludge concentration and temperature could have a pronounced effect. However, we have no practical control over either. We attempted to minimize variations in both—in addition, both were measured. These data could be analyzed later to see if any effect existed for these variables. In setting up the runs not only the determination of potential capacity but also ultimately the optimization of the filter operation was to be investigated.

An examination of the literature indicated that: (*a*) Most of the experimental work has been carried out on sewage plant sludges. (*b*) Most of the work has been done on either leaf tests or pilot unit models of rotary vacuum filters. (*c*) Most of the work has been carried out by rather simple experimental techniques, that is, by changing only one variable, while holding all other variables constant.

This latter technique can lead to erroneous conclusions, particularly if interactions exist between the variables. That is to say, the effect of one of the variables determined in this manner might be substantially different at other combinations of the variables which had been held constant.

To eliminate this possibility, we set up a statistical experiment which would study the linear and quadratic effects of the variables as well as any interactions which might exist between the variables. The plant trials were run on two of three rotary filters used for the filtration of plant sludge.

In order to evaluate the effects of changes in knife cut, cycle speed, and vacuum on filter throughput the following quadratic relationship was postulated:

$$F = \beta_0 + [\beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3] + [\beta_{12} X_1 X_2 + \beta_{13} X_1 X_3] + [\beta_{11} X_1^2 + \beta_{22} X_2^2 + \beta_{33} X_3^2] \quad (1)$$

where

F = filter rate (gph/sq ft),

β_0 = constant (gph/sq ft),

β_i = linear effect of independent variable X,

β_{ij} = interaction effect of variables X and X in combination, and

β_{ii} = quadratic effect of variable X.

The ranges actually covered in the experiment were knife cut—0.00065 in./rev to 0.0065 in./rev, vacuum—10 to 22 in. Hg, and cycle speed—1 to 5 min/rev.

While, in fact, the variables X_1, X_2, and X_3 are continuous, integral approximations to levels of X_1 and X_3 were made because of equipment design. (Technically, this approximation does affect the analysis but only slightly and this is neglected.)

The central problems in the experiment were: (*a*) To determine the validity of Equation 1 as a model relating filtrate throughput F to process variables. (*b*) To estimate efficiently the unknown constants in the relationship. (*c*) To indicate some measure of the precision with which throughput can be predicted.

Each of these questions can be answered by application of several well-known statistical techniques. In this regard it was decided to run a central composite three factor design in the X_1, X_2, and X_3 factor space.

This type of design possesses several advantages (3)(4). This design required 18 levels of X_1, X_2, and X_3 to be run. It was feasible to only make 9 runs on a given day. Thus the experiment was blocked to run the de-

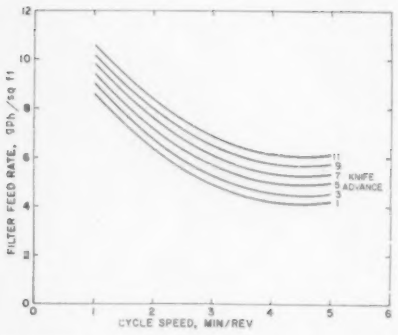

FIGURE 5.—New filter cleaning method.

sign over a two day period and remove average day effects (i.e., temperature, humidity, operator, etc.) from the estimation of the unknown constants.

After the first 18 runs were completed, the procedure for cleaning the filters was changed. To account for this change, the statistical model was revised to incorporate another level of operation. In addition, at this time two duplicate sets of runs were made to determine repeatability and to serve as a check on the replication variance of the other data.

Subsequent to the filter cleaning change, another set of 18 runs were made. An attempt was made to increase the solids concentration of the slurry. In this manner it would be possible to evaluate at least the linear effect of slurry concentration. Conditions, however, were such that effective control over concentrations was not possible. In essence then, both series of 18 runs were made at approximately equal slurry concentrations.

Initially the experiments were analyzed separately by analysis of variance methods. The block effects were trivial in each complete design. Thus, only the effect of cleaning was incorporated in the model.

In evaluating the mean squares for the effects in these analyses, an independent estimate of replication variance (reproducibility) was used. It was taken from the duplicate sets of runs made earlier. On the basis of suitable filter rate tests on the terms representing other effects, lack of fit, and replications, it was found that they were all statistically insignificant.

On the other hand, the linear effects of knife advance and cycle speed and the quadratic effect of cycle speed were statistically significant. The interaction effects, other quadratic effects, and all vacuum effects were insignificant. The replication variance for the two runs was 0.885 and 0.664 for before and after changing the cleaning procedure. An analysis of the repeatability data showed a variance of 0.662, in good agreement with the above.

The analysis also showed the derived equations fit the data well. The replication variance is a direct measure of the ability to predict filter performance. This variance is due to things such as sludge quality, condition of the septum, cake thickness, per cent solids, and per cent oil ability to accurately measure the filter rate. In the case of the filter rate measurement it could only be measured accurately to the nearest 0.5 gph/sq ft. During the runs the solids varied from 1 to 3 per cent and the oil 2 to 7 per cent. A cursory examination was made to determine if solids and/or oil might have some effect. Vacuum was also examined even though it was shown to have

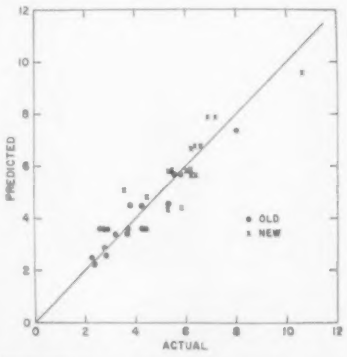

FIGURE 6.—Comparison of actual vs. predicted.

an insignificant effect. No decided effect was shown for any of these variables, although some slight trend existed.

From each experiment the "β" parameters were estimated. The agreement as to sign and magnitude of the coefficients on the statistically significant effects was good with only the effect of level differing.

Appropriate "t" tests comparing the corresponding estimates were performed using the diagonal elements of the inverse of the $(X'X)$ matrix, where X is the design matrix. None were significantly different in the statistical sense. The conclusions based on this analysis of variance are similar to the conclusions reached on the basis of separate analysis.

The revised form of model (I) can now be written as:

$$F = \beta_{01}X_{01} + \beta_{10}X_{10} + \beta_1X_1 + \beta_2X_2 + \beta_{22}X_2^2 \ldots (2)$$

where

X_{01}, X_{10} are dummy variables taking on the values (0, 1) or (1, 0), respectively, depending on the state of the filter.

Inserting the estimates "β" and substituting the variables the equation becomes:

$$F = 9.188\,X_{01} + 11.419\,X_{10} + 0.19537\,K - 3.3927C + 0.3784\,C^2 \ldots (3)$$

Where

K = knife advance, and

C = cycle speed.

A replication variance of 0.775 is shown for this model.

The model is represented schematically in Figure 5 for the data obtained after the new cleaning procedure was employed. The model for the prior data is at a level 2.2 gph/sq ft lower, but with the same trends for the variables. Cycle speed has the most significant effect on filter rate.

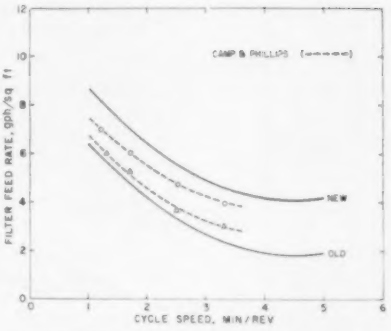

FIGURE 7.—Effect of cycle speed, comparison with literature data.

Figure 6 shows a comparison of the actual vs. predicted data. It indicates a good fit for the equation.

The results appeared to be quite radical both from the standpoint of the theoretical equation for filtration and most of the data published in the literature.

Actual operation of the filters indicated visually that the cake was quite compressible. Initially after increasing the vacuum the blade had to be advanced manually. This compressibility serves to offset the vacuum effect as shown in the theoretical equation

$$\text{Rate} = F\,(\text{Vacuum})^{(1-S)} \ldots . (4)$$

where S is a measure of compressibility approaching unity with increasing compressibility. On this basis the effect of vacuum would be minimized. Even at low knife cuts, at the depth the precoat was being cut it appeared reasonably free of sludge. Sludge was essentially coating out on the surface of the precoat with very little infiltration of sludge particles into the precoat. Thus knife advance would not have a marked effect on filtration rate. This is shown by the graph (Figure 7) where cycle speed has the largest effect on rate.

Literature data reported by Camp and Phillips (5) were compared with our data. These data were obtained on a rotary precoat filter filtering refinery

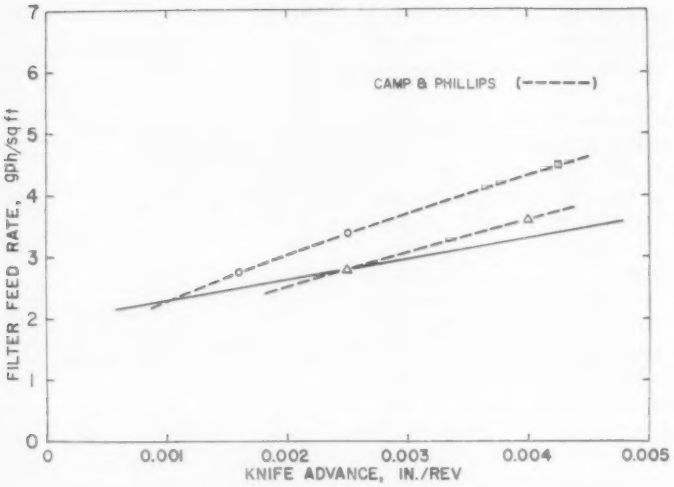

FIGURE 8.—Effect of knife cut, comparison with literature data.

emulsions and separator sediment. Figure 7 is a comparison of the effect of cycle speed for the literature and our data. Both sets of data show good agreement. The effect of knife advance for the data is shown in Figure 8. For our data the rate level was arbitrarily chosen to show the difference in slopes. The literature data were obtained on a less flocculent, more oily sludge. This material is more susceptible to plugging and it would be expected that knife advance would improve filtration rates more than we had observed.

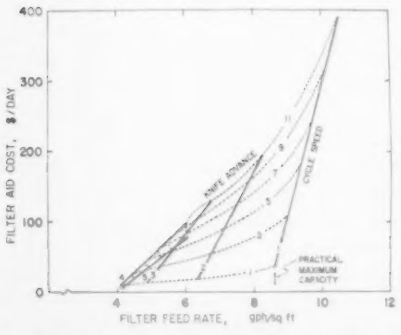

FIGURE 9.—New filter cleaning technique.

Cost

Considering the optimization of the filter process from a cost standpoint, one of the most significant results is that vacuum has little or no effect on filtration rates. This permits minimization of the level of vacuum at which the filters are operated, at least down to the lower levels studied. No attempt was made to estimate the economics of operating at low vacuum levels as compared to higher levels. This would require a separate study to determine a standard for operating the vacuum pumps as a function of the number of filters in operation and the levels of the operating variables. No such study was made but as there are three 150-hp electric vacuum pumps, $20 per day can be saved by shutting down any one.

The filter-aid cost is also a high variable operating cost. The filter rate as a function of knife advance and cycle speed is known as shown in Figure 5. Combining this with the filter-aid cost per unit volume cut we can arrive at a plot which expresses filter-aid cost as a function of filtration rate, cycle speed, and knife advance. This is shown in Figure 9 for data

obtained when the filter was cleaned by the new technique of cleaning. The plot covers only the practical limits of the variable. The following significant points are shown by the graph:

Cycle speed has the most significant effect on increasing filtration rate at minimum cost. Each unit change in cycle speed has a much lesser effect on aid consumption than a unit change in knife advance. Thus the knife advance should be held at 1.0 and cycle speed varied to attain the desired rate.

The practical maximum capacity is shown to be 8.6 gph/sq ft. Although higher rates can be obtained, it is only at rather high costs due to the steep slope of the curve for a cycle speed of 1.0.

Data from the runs made when the filters were cleaned by the old technique were also examined in a similar manner to that above. A comparison of the two showed the new cleaning procedure reduced costs $10 to 15/day, at constant filter rate, and increased the maximum capacity 34 per cent at the same cost.

The study has served to outline the filter capacity from both an academic and practical standpoint and give an insight into the effects of the variables of vacuum filter operations.

References

1. Weston, R. F., and Merman, R. G., "The Chemical Flocculation of a Refinery Waste." Presented at the 19th midyear meeting of the American Petroleum Institute's Division of Refining, Houston, Tex. (1954).
2. Roth, E. R., Helwig, J. D., and Hall, W. A., "Atlantic Selects Air Flotation for Refinery Waste Treatment." Presented at the 25th midyear meeting of the American Petroleum Institute's Division of Refining, Detroit, Mich. (1960).
3. Cochrane, W. G., and Cox, G. M., "Experimental Design."
4. "Design and Analysis of Industrial Experiments." O. L. Davis, Editor.
5. Camp, E. Q., and Phillips, C., "Pilot Unit Studies on Filtration of Refinery Emulsions and Separator Sediment." *Oil & Gas Jour.*, **48**, 46, 214.

MONTHLY CONTRACT AWARDS—SEWAGE TREATMENT WORKS AND COLLECTING SEWERS AS REPORTED BY THE PUBLIC HEALTH SERVICE (MILLIONS OF DOLLARS)

Month (1961)	Treatment		Sewers		Total	
	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative
Jan.	24.4	24.4	22.4	22.4	46.8	46.8
Feb.	33.5	57.9	22.3	44.7	55.9	102.7
Mar.	47.1	105.0	30.1	74.8	77.2	179.9
Apr.	30.6	135.6	33.5	108.3	64.1	244.0
May	50.9	186.5	39.3	147.6	90.2	334.2
June	37.9	224.4	42.6	190.2	80.5	414.7
July	21.7	246.1	29.9	220.1	51.6	466.3
Aug.	46.8	292.9	53.1	273.2	99.9	566.2

OPERATIONAL PROBLEMS OF PACKAGE ACTIVATED SLUDGE PLANTS

Richard S. Howe

Introduction

Problems affecting the operational efficiency of extended aeration activated sludge plants, noted during field studies, are as follows:

1. Hydraulic shock loads due to pumping of raw waste into the aeration tank.
2. Velocity of influent flow not great enough to press majority of solids into comminutor.
3. Foaming in aeration tank.
4. Inadequacy of sprays in coping with foam problem.
5. Inadequate control of air supply:
   (*a*) Excessive turbulence in aeration tank.
   (*b*) Denitrification.
6. Excessive return sludge rates.
7. Clogging of return sludge lines by foreign matter.
8. Scum layer on sedimentation tank.
9. High grease content wastes.
10. Temperature.

Of primary concern are the problems affecting the sedimentation process because the settling tank holds the key to satisfactory operation of these units. Plants receiving wastes on an intermittent basis from a pumping station cause the sludge blanket to rise and large quantities of solids to be lost in the effluent. Two detrimental effects are incurred by the loss of solids.

1. The mixed liquor solids concentration decreases.
2. The effluent BOD is increased above allowable limits.

Decreases in mixed liquor suspended solids as high as 1,500 mg/l per month have been noted.

The key to the problem of disturbed settling appears to be the pumping rate and frequency of pumping. The pumping rate is significant because pumps being used would not operate at low pumping rates (20 gpm or less) consistently. The frequency of pumping is important because the wet well may be such that long lag periods occur between pumpings. Therefore, more frequent pumping of smaller volumes or the use of variable speed pumps to pace the sewage flow should facilitate plant operation where pumping is required. Intermittent introduction of the raw waste also affects the biological operation. The operation of these units is theoretically based on the premise that microorganisms will be maintained at a constant point on the growth curve. McKinney *et al.* (1) state that continuous feeding is essential to the maintenance of constant growth of the biological population. Therefore, the nearer actual field installations approach continuous feeding, the more efficient the operation would be expected, other conditions being equal.

Air Volume Control

Inadequate control of the air being supplied to unit is one of the major mechanical problems confronting the operator of a small unit activated sludge plant. The majority of the

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This paper was presented at the Spring Meeting of the New England Water Pollution Control Association, June 7, 1961.

units on the market today are equipped with positive displacement air blowers on a fixed base. Therefore, the only available means of varying the air is by changing the sheaves on the blower. This does not provide adequate control and has the added disadvantage of being time-consuming.

Excessive turbulence in the aeration tank resulting from inadequate air control has a detrimental effect on clarification when the aeration and settling sections are housed in a single tank and separated only by a baffle. The energy imparted to the mixed liquor due to this turbulence is carried over into the settling section and results in poor clarification.

Denitrification

Denitrification also stems from the basic cause of excess O_2 being supplied and thereby providing the driving force for nitrification. The denitrification then occurs in the settled sludge causing nitrogen gas to be formed and on its release bringing the sludge to the surface. Denitrification must be preceded by nitrification and since excess oxygen is the cause of nitrification the solution, obviously, is to decrease the quantity of air being supplied. This problem will be encountered most frequently at an installation operating below the organic design load of the plant. The most satisfactory solution appears to be the incorporation of an automatic timer into the diffuser system, or use of a turbine blower. With these the amount of air being supplied can be controlled within relatively loose limits.

Sludge Recirculation

Excessive rates of sludge recirculation have an adverse effect on settling in two ways. First, the high rates result in effectively turning over the entire volume of the settling tank several times each hour. Second, the floc is torn apart, which decreases its ability to settle. It is a recognized fact that the recirculation rate in a complete mixing unit must be greater than in a conventional activated sludge plant. Tapleshay (2) states the return rate is usually 100 per cent and frequently as much as 300 per cent of the design flow. McKinney (3) reported that total oxidation systems required sludge return rates of from 100 to 200 per cent of the waste flow due to the high MLSS concentrations. Field installations have been observed, however, with rates upwards of 2,000 per cent of the design flow and many times greater when the recycle ratio is based on the actual average flow.

Return Sludge Discharge

Tapleshay (2) reported that return sludge discharge rates can be controlled by controlling the air volume applied to the air lift pump. This is true, but the means provided for accomplishing this end are inadequate in most instances and furthermore, when the return sludge rate is decreased to within reasonable limits, the lines clog almost immediately. Therefore, it is felt the only reason the rates are maintained at such high levels is to prevent clogging.

The sludge return lines clog primarily due to leaves and other foreign matter which either falls or is blown into the tank. Knox (4) reported clogging of sludge lines was the most frequent cause of trouble in Ohio and will adversely affect effluent quantity if allowed to continue. To prevent leaves from entering the tank a covering of chicken wire or similar material is recommended.

Grease Disposal

Plants receiving highly concentrated kitchen wastes containing large quantities of grease will develop scum layers. These are a continual nuisance, not only from the standpoint of septicity,

but also disposal. Disposal means one of two things, either returning it to the aeration tank or completely removing it from the unit and disposing of it by incineration or burial. The method chosen will depend on characteristics of the scum layer itself.

When the layer consists primarily of biological floc held together in a cohesive mass by small quantities of grease or is made up entirely of sludge, then the recommended procedure is to return it to the aeration tank. However, if scum is primarily grease, in the form of "balls," floating on the surface, then disposal should properly be by incineration or burial. Knox (4) stated that all scum should be removed from the system and never returned to the aeration tank.

Temperature Effect

Observations at various plants indicate low temperatures result in a more turbid effluent than obtained during warm weather. Ludzack *et al.* (5) report that *Sphaerotilus* apparently has a better competitive position at low temperature than at high temperature. Microscopic examinations of various sludges taken during winter showed a predominance of filamentous organisms accompanied by a turbid effluent.

Conclusions

1. Intermittent pumping of raw waste into the aeration tank has detrimental effect on settling.
2. Most plants have inadequate control of air supply to both the aeration tank and the air lift sludge return pump.
3. Sludge scraping and skimming should facilitate plant operation.
4. Regular maintenance is required if the complete mixing systems are to give consistent operation.

References

1. McKinney, R. E., Symons, J. M., Shifrin, W. G., and Vezina, M. J., "Design and Operation of a Complete Mixing Activated Sludge System." *Sewage and Industrial Wastes*, **30**, 3, 287 (Mar. 1958).
2. Tapleshay, J. A., "Total Oxidation Treatment of Organic Wastes." *Sewage and Industrial Wastes*, **30**, 5, 652 (May 1958).
3. McKinney, R. E., "Complete Mixing Activated Sludge." *Water and Sewage Works*, **107**, 2, 69 (Feb. 1960).
4. Knox, H., "Current Observations on Aerobic Digestion Plants in Ohio." Presented at the West Virginia Sewage and Industrial Wastes Association Meeting, Mar. 1960.
5. Ludzack, F. J., Schaffer, R. B., and Ettinger, M. B., "Temperature and Feed as Variables in Activated Sludge Performances." THIS JOURNAL, **33**, 2, 141 (Feb. 1961).

BIOCHEMICAL OXIDATION OF THE LOWER FATTY ACIDS

P. E. Gaffney and H. Heukelekian

Results of preliminary investigations dealing with the biochemical oxygen demand of the lower fatty acids and the experimental factors affecting these results were reported earlier (1) (2). It was shown (1) that L-values calculated according to the "moments" method (3) were in good agreement with actual observed 20-day BOD values when nitrate was used as a nitrogen source in the dilution water in order to prevent nitrification. The k-values for the fatty acids, ranging from 0.19 to 0.26, are comparable to those reported for sewage by Ruchhoft *et al.* (4). This similarity of results was unexpected, since the fatty acid oxidation curves are very dissimilar to sewage oxidation curves (the fatty acids show long lag periods after which there is a very rapid rate of oxidation followed by an abrupt cessation of measurable oxygen-uptake). It became necessary, therefore, to evaluate the rate parameter used when studying the oxidation of such readily available organic compounds.

The present studies are divided into the following: (*a*) evaluation of oxidation rate parameters, (*b*) factors affecting lag period, oxidation rate, and ultimate oxygen demand, and (*c*) carbon balance studies.

A. EVALUATION OF OXIDATION RATE PARAMETERS

Results and Discussion

Table I shows the results of a number of fatty acid experiments. Values for k and L for the curves were calculated by the "moments" method (3), based on seven 1-day increments after the lag period. In order to compare these values with actual observations, it was necessary to employ a different rate parameter (Δt). The expression Δt is defined as: "the interval of time required for exertion of 90 per cent of the ultimate oxygen demand beyond the lag period" and is calculated as follows:

$$\Delta t = t_{90} - t_{\text{lag}} \quad \ldots\ldots\ldots (1)$$

where

t_{90} = the time at which 90 per cent of the ultimate oxygen demand has been exerted, and

t_{lag} = the time at which the lag period ceases and the maximum oxygen-uptake rate begins.

The t_{lag} is obtained by extending the straight-line slope of the curve (logarithmic oxidation phase) to the time axis and determining the value of the point where it intercepts the axis (Figure 1). The curve (Figure 1) is typical of all data obtained, in that a straight line can be drawn through the values during the maximum oxidation

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A portion of the paper was presented at the 1958 Meeting of the Southeastern Branch of the Society of American Bacteriologists at Radium Springs, Ga.

phase. When the rate of oxidation in the logarithmic (maximum) oxidation phase decreases, the value of Δt increases.

The data in Table I show that: (*a*) The calculated *L*-values compare fairly well with the oxygen demand of the acids observed after 20 days incubation, a fact which provides sufficient justification for interchanging the terms "20-day" and "ultimate oxygen demand." (*b*) There is no constant relationship between the *k* value and Δt; i.e., where one test compared to another may show a higher Δt value indicative of a lower rate, the *k*-value may increase indicating a higher rate. Although, as in some cases, Δt increased while *k* decreased, meaning that the rate decreased as indicated by both parameters. (*c*) In certain instances, when the two different tests were compared, the *k*-values were essentially the same while the Δt value varied widely; in other instances, where the differences in Δt were within the experimental error (0.4 day), there were apparent differences in *k*-values. (*d*) Where the Δt values were 1.5 days or less (indicating a very high rate of oxidation), it was not possible to obtain *k*- and *L*-values by this method.

TABLE I.—Comparison of Calculated *k*- and *L*-Values with Observed Δt and 20-Day Oxygen Demand Values for the Lower Fatty Acids

Compound	Conc. (mg/l)	*k*	Δt (days)	O_2 Demand (parts/part)*	
				20-day	*L*
Acetate	20	0.19	3.3	—	0.84
	100	0.39	3.2	—	0.78
	1,000	0.33	3.9	—	0.80
	10,000	0.19	4.1	—	0.84
	10,000	—	1.5	0.78	—
	10,000	0.21	3.9	0.82	0.83
	10,000	0.19	2.2	—	0.76
	10,000	0.19	3.2	0.82	0.87
	10,000	0.26	2.4	0.76	0.80
	10,000	0.25	2.3	0.79	0.82
	10,000	0.30	2.0	0.79	0.80
	10,000	0.35	1.9	0.77	0.75
	10,000	0.21	3.0	0.75	0.78
↓	—	—	1.2	0.70	—
Propionate	100	0.35	4.0	1.16	1.10
	1,000	0.20	3.8	1.22	1.25
	10,000	0.31	3.0	1.11	1.13
↓	10,000	0.26	3.4	1.25	1.26
Butyrate	100	0.37	3.0	1.42	1.41
	10,000	0.28	2.4	1.42	1.47
	10,000	0.29	2.5	1.42	1.43
↓	10,000	0.26	2.6	1.35	1.37
Valerate	10,000	0.18	4.7	1.46	1.49
	10,000	0.15	4.5	1.46	1.55
	10,000	0.15	4.5	1.47	1.55
↓	10,000	0.31	2.4	1.54	1.46
Caproate	10,000	0.22	2.7	1.70	1.74
Caprylate	10,000	0.26	2.5	1.67	1.72
Caprate	10,000	0.24	2.4	1.42	1.50

* Parts of O_2 per part of oxidizable organic radical.

When the days within the lag period were included in the calculations, it was found impossible to fit the data into the method, and *k*- and *L*-values could not be obtained. The values presented in Table I were obtained by using seven 1-day oxygen demand increments after the lag period; this 7-day period included a significant portion of the maximum stationary phase.

Attempts were made (with several tests) to use a shorter period that would include in the calculations only the measurements made in the logarithmic oxidation phase. When the number of 1-day increments was decreased, the *k*-value decreased and the *L*-value increased to a level exceeding the theoretical oxygen demand. This tendency is the exact opposite to that observed by Orford (5) with sewage oxidation curves, and can be explained on the basis of the following considerations:

1. Oxidation of sewage proceeds at a constantly decreasing instantaneous rate and thus approximates a monomolecular reaction. The *k*-value actually indicates the rate at which the real rate (oxygen-uptake per unit time) decreases over a particular portion of the curve. The value *k* may

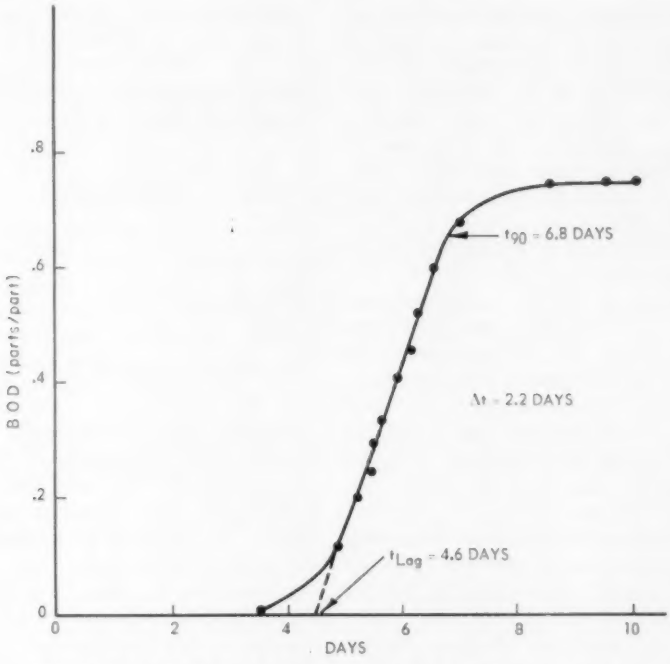

FIGURE 1.—Method of calculating Δt in connection with oxygen demand of 10,000-mg/l acetate.

be defined as "the fraction of oxygen demand remaining to be exerted that is exerted per day." The rate and extent of oxidation for the principal components (soluble and particulate matter) of sewage have been shown by Balmat (6) and Orford (5) to be different. The soluble matter is oxidized at a very high rate during the first two days until it disappears. It contributes approximately only one-third of the total oxygen demand of the sewage. The particulate fraction is the most important because it contributes two-thirds of the total oxygen demand. Its rate of oxidation is low due to limitations imposed by the rate of hydrolysis. If longer periods of time are included in calculation of the constants, the L-value increases because more oxygen demand is exerted (by the particulate fractions) and the k-value decreases due to inclusion of the lower rate of oxidation of this fraction.

2. Oxidation of fatty acid proceeds at a relatively constant rate until the reaction is complete. At this point oxygen-uptake ceases abruptly. Inclusion of longer periods of time in these calculations results in a decreasing L-value because no appreciable oxygen-uptake is occurring. Since the L-value decreases, k must increase.

3. Theoretically, a straight-line curve would show an infinite L-value and k would naturally tend toward zero. Since the fatty acid oxidation curves approximate straight lines in the logarithmic oxidation phase, the k-values obtained from only points in this portion of the curve would be very low, even though oxygen is being consumed at a high rate.

The use of the k-value in interpreting fatty acid oxidation rates as well

as other readily available soluble organic compounds is thus limited because the duration and number of time increments used in the calculation constitute the principal factor affecting the value obtained. It may also be interesting to note that the "two-point" method of Rhame (7) and Orford's logarithmic method (5) were tested and found to be subject to the same limitations.

Although Δt has been used as a rate parameter in analyzing the curves obtained, it is not an expression of "rate" (oxygen-uptake per unit time) in the strict sense of the word, since the units of Δt are expressed as "days." The value is used to define the number of days required for exertion of 90 per cent of the ultimate oxygen demand with a given compound. Its principal usefulness is that it allows tabular comparison of two or more different sets of data, thus eliminating the need for space-consuming graphs. In comparing two oxidation curves in which one shows that a longer period of time is required for exertion of 90 per cent of the ultimate oxygen demand, the rate of oxidation would be less, and a higher Δt value would be obtained for that curve.

Actual rates of oxidation can be calculated when the amount of oxygen-uptake in terms of parts of oxygen consumed per part of compound is known. For example, if 90 per cent of the ultimate oxygen demand with acetate equals 0.72 part per part and the Δt value is 3.0 days, the rate of oxidation is 0.72/3.0 or 0.24 part of oxygen consumed per part of acetate per day. This value would be the average rate of oxidation during the logarithmic phase of fatty acid oxidation.

Conclusions

The purpose of this phase of the study was to evaluate the parameters used in calculating oxidation rates during BOD studies on the lower fatty acids. The conclusions derived from these investigations are as follows:

1. The common method of expressing oxidation rate (k-value) is not applicable to BOD results of the lower fatty acids due to: (a) long lag periods with high substrate concentrations, (b) rapid oxygen-uptake after the lag periods cease, and (c) the leveling-off of the oxygen-uptake curves subsequent to exertion of the maximum oxygen demand. On this basis it was necessary to develop a different rate parameter based on the actual shape of the oxygen-uptake curve.

2. The rate parameter determined to be more applicable to BOD curves on such readily available (soluble) substrates is the expression "Δt", which is defined at the length of time required for exertion of 90 per cent of the ultimate oxygen demand beyond the lag period. This value represents the average rate of oxidation within the logarithmic phase and eliminates error due to long lag periods.

B. FACTORS AFFECTING LAG PERIOD, OXIDATION RATE, AND ULTIMATE OXYGEN DEMAND

Earlier work (1) dealt with a consideration of the effects of the BOD method employed, cations, substrate concentration, quality and concentration of seed, and nitrogen and phosphorus requirements on the 5-day and 20-day BOD values of the lower fatty acids. The purpose of the studies reported herein deals with the effects of substrate concentration, initial pH, adaptation, and initial numbers of organisms in the seed on the length of the lag period, oxidation rate, and oxygen demand values.

TABLE II.—Effect of Substrate Concentration on Lag Period, Rate of Oxidation, and Oxygen Demand

Substrate	Substrate Conc. (mg/l)	Lag Period (days)	Δt (days)	5-Day BOD (parts/part)*	20-Day BOD (parts/part)*
Acetate	10	0.3	1.9	0.78	0.82
↓	20	0.4	3.1	0.72	0.75
↓	100	0.8	3.2	0.77	0.80
↓	1,000	0.8	3.9	0.75	0.79
↓	10,000	5.2	—	0.03	—
Propionate	100	0.2	4.0	1.08	1.16
↓	1,000	1.2	3.8	1.10	1.22
↓	10,000	3.2	3.0	0.98	1.11
Butyrate	1,000	0.5	3.0	1.39	1.42
↓	10,000	1.8	2.4	1.35	1.43

* Parts O_2 per part of substrate.

Methods and Results

Fatty Acid Concentration

A series of tests was conducted with three fatty acid substrates in varying concentrations using the jug dilution method (8) for 10- and 20-mg/l acetate and the Warburg respirometer for higher concentrations of acetate, propionate, and butyrate. All tests were performed according to the procedures outlined in "Standard Methods" (9). The results of these tests are presented in Table II.

The data (Table II) show that as substrate concentration increased, there was a corresponding increase in lag period and, for acetate, an increase in Δt or decrease in rate of oxidation. However, Δt decreased with increasing concentration of either propionate or butyrate, indicating that, as far as these compounds are concerned, increase in concentration results in an increase in the relative rate of oxidation (parts of oxygen per part of substrate per day). With all substrates (including acetate) there was an increase in the absolute rate of oxidation (mg/l oxygen per unit of time) with increasing concentration of organic material.

Only with 10,000-mg/l acetate was a concentration effect on the 5-day BOD due to an extremely long lag period. Within the normal experimental variation of the tests, no effect of substrate concentration was observed with regard to ultimate (20-day) BOD.

Numbers of Initial Organisms

Previous results (1) showed that the variation in lag periods with acetate and valerate (using 10,000 mg/l) depends on source and sampling time of the sewage seed; for instance, the lag periods with acetate seeded with 10-per cent sewage by volume ranged from 0.7 to 5.2 days. Further analysis of these preliminary curves indicated that the Δt values ranged from 1.2 to 3.9 days. Thus, the 5-day BOD is greatly affected by the length of the lag period and the subsequent rate of oxidation. It was also shown (1) that a constant food: seed ratio of 100:1 with 100- and 10,000-mg/l acetate failed to eliminate the lag with high substrate concentration. In view of the fact that the length of the lag period is generally considered to be principally affected by numbers of organisms, it was considered desirable to test this hypothesis.

In order to determine the effect of numbers of initial seed organisms on the lag period and rate of oxidation, three tests using 10,000-mg/l acetate were made on different sewage samples at a constant seed concentration of 10 per cent by volume. Warburg BOD curves were obtained on each up to a

TABLE III.—Effect of Numbers of Initial Seed Organisms on Oxygen Demand of 10,000 mg/l Acetate

Determination	Sample No.		
	1	2	3
Avg no. bacteria/ml*	21,500	54,000	87,500
Lag period (days)	1.0	4.5	1.5
Δt (days)	1.2	2.4	3.0
5-day BOD (parts/part)	0.67	0.15	0.69

* In Warburg flask.

period of 20 days. Simultaneously, an agar medium for counting the numbers of organisms in the sewage seed was prepared using 2-per cent plain agar and 10,000-mg/l acetate, plus all other nutrients in concentrations identical to those used in the BOD dilution water. In order to count only those organisms aerobically utilizing the acetate (to simulate conditions in the Warburg flask) 1-ml portions of serial ten-fold dilutions of the sewage samples were pipetted onto the surface of the previously solidified agar and spread over the surface of the plate. The plates were then placed in a 37°C-incubator for one hour with the lids slightly tilted in order to evaporate the dilution water, after which they were closed and inverted; the colonies were counted after incubation at 20°C for 5 days. The results of these tests are presented in Table III.

The data (Table III) show that, in the test with the lowest initial number of bacteria (21,500 ml), the shortest lag period and highest rate of oxidation were observed. As the numbers of initial organisms increased, Δt also increased, meaning that the maximum rate of oxidation actually decreased. It is recognized that the number of organisms in the three tests are in the same order of magnitude, and the differences may not be such as to constitute a good basis for contrast. It may be concluded, nevertheless, that there is no trend toward either shorter lag periods or more rapid oxidation rates, or both, with apparently increasing numbers of organisms in the seed.

Seed Adaptation

It was shown previously (1) that when low 5-day BOD values were initially obtained with 10,000-mg/l acetate, butyrate, and valerate, using sewage seed, it was possible to adapt a seed to give higher 5-day values.

It was not definitely known whether adaptation merely reduces the lag pe-

TABLE IV.—Effect of Adaptation on Lag Period, Δt, and Oxygen Demand Values of 10,000-mg/l Fatty Acid Substrates

Substrate	Sewage Seed					Adapted Seed*				
	Lag Period (days)	Δt (days)	O_2 Demand (parts/part)			Lag Period (days)	Δt (days)	O_2 Demand (parts/part)		
			5 Days	10 Days	20 Days			5 Days	10 Days	20 Days
Acetate No. 1	5.2	—	0.03	—	—	1.0†	1.0	0.75	0.75	0.76
Acetate No. 2	1.0	1.8	0.73	0.74	0.75	1.6	2.1	0.72	0.79	0.80
Propionate	3.2	2.1	0.98	1.10	1.15	2.4	2.9	1.05	1.21	1.22
Butyrate	1.7	2.2	1.36	1.40	1.42	0.5	2.7	1.36	1.40	1.42
Valerate	5.4	5.2	0.08	1.24	1.44	0.8‡	4.8	1.29	1.38	1.44
Caproate	1.7	2.9	0.64	1.46	1.54	0.5	4.1	1.46	1.63	1.66
Caprylate	2.2	3.2	1.47	1.60	1.66	1.6	4.2	1.45	1.69	1.70
Caprate	4.6	1.2	0.34	1.18	1.19	2.4	2.4	1.27	1.39	1.40

* Usually involved only one transfer of seed material.
† Three transfers.
‡ Two transfers.

TABLE V.—Effect of Adaptation on the Relationships Between 5-Day, 20-Day, and Theoretical Chemical Oxygen Demand of the Fatty Acids

Compound	TOD* (parts/part)	Sewage Seed			Adapted Seed		
		5/20 (%)	5/TOD (%)	20/TOD (%)	5/20 (%)	5/TOD (%)	20/TOD (%)
Acetate	1.10	—	3	—	98	68	69
↓	1.10	97	66	68	90	66	73
Propionate	1.50	85	65	77	86	70	81
Butyrate	1.80	96	76	79	96	76	79
Valerate	2.04	6	4	71	90	63	71
Caproate	2.21	42	29	70	88	66	75
Caprylate	2.44	89	60	68	84	51	70
Caprate	2.60	28	13	46	91	49	54

* TOD—theoretical chemical oxygen demand based on complete oxidation to carbon dioxide and water.

riod by having larger numbers of seed organisms or whether it serves to increase the logarithmic oxidation rate due to a transfer of organisms that are in an improved physiological state, or both.

The data in Table IV are presented in an attempt to explain the actual mechanism of the beneficial effect of adaptation on the 5-day BOD of 10,000 mg/l of the fatty acids studied.

The procedure used to obtain these results involved an initial test using 0.1- to 10.0-per cent domestic sewage as seed. After the maximum oxygen demand had been observed, the resultant liquor was used to seed a fresh fatty acid preparation. In every instance, the concentration of this "adapted seed" used was 10 per cent by volume.

Table IV shows that adaptation resulted in appreciable reduction in the lag periods except in one case (second test with acetate) where a low lag period was observed with unadapted seed. This will be discussed later in more detail. It was not possible, however, to completely eliminate the lag period even with subsequent transfers of seed material.

Generally, adaptation resulted in an increased Δt value. There is no satisfactory explanation as to why this increase occurred because it means that the rate of oxidation in the logarithmic phase was actually decreased. It may be related to the fact that the organisms were respiring endogenously when transferred. However, even with the increase in Δt, the 5-day BOD with adapted seed was increased significantly when a low value was initially obtained using the sewage seed. This was due to the reduction in lag period.

The effect of adaptation on the relationships between the 5-day, 20-day, and theoretical oxygen demand is shown in Table V. (The data in this table are derived from the results in Table IV.)

Caprate appears to have been less susceptible to oxidation than the other compounds in this group. (The maximum observed BOD was 54 per cent of the TOD while the range for the other acids was 69 to 81 per cent.) This could be due to the fact, that at a concentration of 10,000 mg/l, caprate formed an emulsion which most likely rendered it less available for biological oxidation than the older soluble compounds.

With 0.1- to 10.0-per cent sewage seed, the 5-day oxygen demand values represented from 6 to 97 per cent of the 20-day value (or ultimate oxygen demand). Adaptation had the effect of increasing this range to 84 to 98 per cent, indicating that oxidation was

essentially complete by the 5th day due to reduction in lag.

When using sewage seed, the 5-day values represented from 3 to 76 per cent of the theoretical chemical oxygen demand. Adaptation narrowed this relationship to 49 to 76 per cent.

The 20-day values represented from 46 to 79 per cent of the theoretical when sewage was used as seed. Adaptation had the effect of increasing this range to 54 to 81 per cent. This increase in observed 20-day values is not considered significant, indicating that the maximum (or ultimate) oxygen demand values of the fatty acids represent an average of approximately 70 per cent of the theoretical when using either sewage or adapted seed. If the values obtained with caprate were eliminated from the calculations, the 20-day value represents between 68 to 81 per cent of the theoretical chemical oxygen demand, regardless of the type of seed used.

The following conclusions are derived from these experiments:

1. Adaptation is responsible for a considerable reduction in the lag periods initially observed when sewage is used as seed for oxidation of 10,000-mg/l fatty acid. Adaptation, however, does not increase the rate of oxidation once the lag is over. With adapted seed, the observed 5-day oxygen demand is usually higher than with sewage seed, but the ultimate (20-day) oxygen demand values are comparable with either seed material.

2. More consistent and reliable 5-day oxygen demand values are obtained for 10,000-mg/l fatty acid when adapted seed is used. The observed 5-day value with adapted seed represents approximately 65 ± 7 per cent of the theoretical chemical oxygen demand based on complete oxidation to carbon dioxide and water. With sewage seed the 5-day value represents 40 ± 27 per cent of the theoretical chemical oxygen demand.

3. The average maximum (or ultimate) oxygen demand values observed after 20 days represent approximately 68 to 81 per cent of the theoretical chemical oxygen demand.

During these adaptation experiments, it was observed in certain cases, i.e., test 2 with acetate (Table III and Figure 2), that the lag period using adapted seed was longer than in the initial curve with sewage. This occurred only when the final liquor (from the sewage test) to be used as "adapted

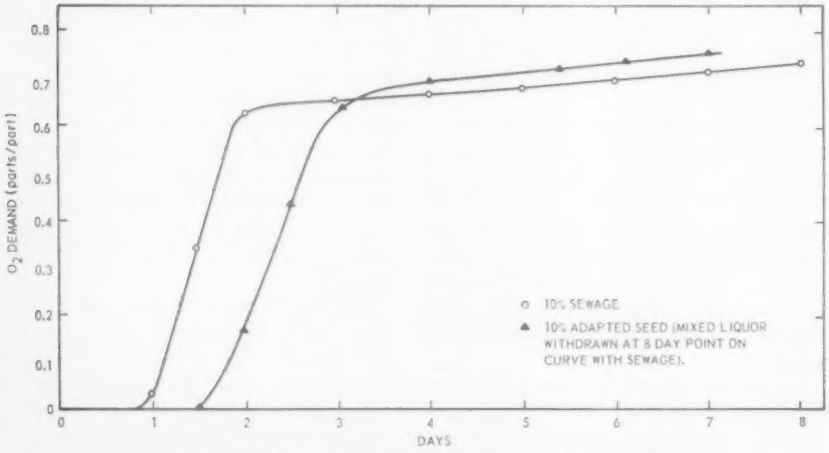

FIGURE 2.—Oxidation of 10,000-mg/l acetate for two mixtures.

seed'' was transferred to a fresh preparation 5 days after the maximum oxygen demand had been observed. This means that the organisms had been respiring endogenously for 5 days prior to transfer to a fresh acetate preparation.

Thus, it was desirable to determine the optimum point in an oxidation curve at which the organisms would be most capable of rapidly oxidizing fresh substrate preparation, and to compare the lag periods and oxidation rates with the numbers of organisms in the seed. Accordingly, a test was set up using 10,000-mg/l acetate and 10- per cent sewage seed. Oxygen uptake measurements were made for 20 days. At three different times during the oxidation period aliquots of the mixture were transferred to three separate preparations of fresh substrate. The three transfer points were the early and late logarithmic oxidation phases and the maximum stationary phase (approximately one day after measurable oxygen uptake ceased). Plate counts (using the procedure previously described)were made on the initial sewage and on the three ''adapted'' seeds. The results are presented in Table VI and Figure 3.

TABLE VI.—Effect of Numbers of Organisms and Time of Seed Transfer on Lag Period and Δt Observed in Subsequent Oxidation of 10,000 mg/l Acetate

Seed Organisms per ml (× 1,000,000)	Time t of Seed Transfer (days)	O_2 Demand at Time t (parts/part)	Lag Period (days)	Δt (days)
0.054	0 (10% sewage)	—	4.5	2.4
20	5.5	0.30	0.7	2.3
73	7.0	0.68	0.7	2.0
123	9.0	0.75	1.0	1.9

A 4.5-day lag period was observed with the sewage seed. The ''early logarithmic phase'' is considered to have lasted 1 day—from the end of the lag

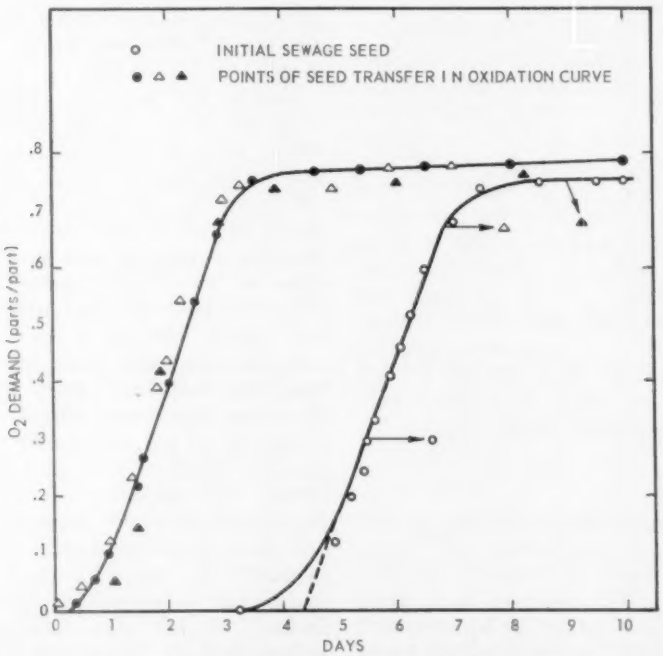

FIGURE 3.—Effect of adaptation on oxidation of 10,000-mg/l acetate.

TABLE VII.—Effect of Initial pH on Oxidation of 1,000 mg/l Acetate

Initial pH	Lag Period (days)	Δt (days)	O_2 Demand (parts/part) at		Final pH at 10 days
			5 days	10 days	
5.2	3.9	5.4	0.11	0.57	8.3
5.7	3.3	4.8	0.16	0.70	8.3
6.7	2.6	2.5	0.65	0.69	8.2
7.2	2.6	2.5	0.58	0.66	8.4
7.8	2.0	3.6	0.57	0.68	8.2
8.5	1.8	2.5	0.54	0.70	8.2
9.9	3.8	2.4	0.63	0.73	8.1

period to 5.5 days where the BOD exerted was 0.30 parts/part. At 7.0 days, the late logarithmic phase was almost over; oxygen uptake actually ceased after 8.0 days.

Adaptation reduced the 4.5-day lag period appreciably, but had little or no effect on the Δt value or the ultimate oxygen demand value. (The differences in Δt are considered to be within normal variation.) The small differences in lag periods (0.7 to 1.0 day) with the three "adapted seeds" that resulted indicated that the seed containing 20 million organisms per milliliter was capable of attacking the acetate as rapidly as the seed containing 73 million organisms per milliliter. On this basis, it is concluded that maximum reduction in lag period can be obtained if seed is transferred while the organisms are actively oxidizing the substrate. If the organisms are transferred a significant length of time, i.e., 5 days after endogenous respiration has begun, their capacity for accelerated oxidation of a fresh substrate preparation is lost (Figure 2).

Initial pH

Since industrial wastes may be discharged over a wide range of pH levels, it was desirable to determine whether the fatty acid contained in a waste would be oxidized by the bacteria, and what effect the various initial pH levels would have on the lag period, the rate of oxidation, and the extent of oxidation.

Table VII shows the results of an experiment in which seven different preparations of 1,000-mg/l acetate were adjusted to various pH levels (5.2 to 9.9) prior to the addition of 1.0-per cent sewage seed. The cumulative oxygen demand and pH changes were measured for a period of 10 days.

In addition to the results shown in Table VII, it was also observed that in each test, when as little as 0.1 part per part oxygen demand had been exerted the pH of the mixed liquor leveled off around 8.2 to 8.5 and independent of the initial pH.

The shortest lag periods (1.8 to 2.0 days) were obtained at pH 7.8 and 8.5, and the lag increased as the initial pH deviated from this range to either the acid or alkaline side. There was no constant trend or relationship between initial pH and the Δt values. The highest rate (on the basis of Δt) in the logarithmic phase (after the lag period) was obtained when the initial pH was 9.9, and the lowest was obtained at a pH of 5.2.

Due to the long lag periods and large Δt values, all the 5-day BOD values were affected with the exception of the test in which the initial pH was 6.7. In the test with an initial pH of 5.2, the combination of long lag period and slow rate had an effect on the 10-day oxygen demand. After 10 days the final pH in each test ranged from 8.1 to 8.4.

It was concluded from this experiment that initial pH levels of 5.2 to 9.9 have significant effects on the length of the lag period and the subsequent oxidation rate of 1,000-mg/l acetate, but apparently do not affect the maximum oxygen demand.

In these studies no attempt was made to buffer the test solutions in order to maintain a neutral pH during oxidation. It has been observed that independent of initial pH, the pH after 0.1 part per part oxygen demand

has been exerted tends toward a level of 8.1 to 8.4. The question arose as to whether this trend toward the alkaline side during oxidation is responsible for onset of the maximum stationary phase in the oxidation curves. If this were the case, the organisms oxidizing the fatty acids may be inhibited and oxidation would cease, although fatty acid may still be present. The effect of this pH trend may, therefore, be responsible for the low ultimate oxygen demand values in relation to the theoretical.

In order to test for this possibility and to maintain the pH close to neutrality during oxidation, the following experiment was conducted. Three preparations of 1,000-mg/l acetate using 1.0-per cent sewage were set up in the following manner: (*a*) Glacial acetic acid was added directly to a solution containing 90-per cent buffer * by volume and 20-per cent dilution water containing all of the necessary minerals. (*b*) Glacial acetic acid neutralized to pH 7.0 with sodium hydroxide was added to 80-per cent buffer. (*c*) Glacial acetic acid neutralized to pH 7.0 with sodium hydroxide was added only to dilution water. Changes in pH and the oxygen demand of each test were determined manometrically for 7 days because at this time oxygen uptake ceased. The results of this experiment are presented in Table VIII.

Table VIII shows that direct addition of unneutralized acetic acid to the buffer resulted in a final pH (after oxidation) of 7.2 compared with the much higher pH values obtained in the tests where sodium acetate was diluted in the buffer or dilution waters. The comparable maximum oxygen demand values obtained in all three tests, however, indicated that the final pH of 8.1 to 8.4 usually obtained has no effect on the maximum oxygen demand of the fatty acid and eliminates speculation concerning the possibility of the alkaline pH being responsible for the large difference between actual and theoretical oxygen demand.

Discussion

The differences in lag periods and oxidation rates of acetate due to low initial pH levels of 5.2 to 5.7 may be explained on the basis of two possible alternatives: (*a*) There may be a selection of different bacterial species at various initial pH levels and these different species oxidized acetate at a different rate. (*b*) At each initial pH level, the same organism may be responsible for the oxidation but, because of the pH difference, oxidation proceeds at a different rate. Available data would tend to minimize the possibility of the second alternative with regard to pH 5.2 and 5.7, since, in each test, after an oxygen demand

* 29.6 ml of 0.1N NaOH plus 50.0 ml of 0.1M KH_2PO_4 diluted to 100 ml units distilled water. pH = 7.0.

TABLE VIII.—Effect of Direct Addition of Glacial Acetic Acid to Buffer on Final pH and Maximum Oxygen Demand of 1,000 mg/l Acetate

Days	HAc 80-per cent Buffer		NaAc 80-per cent Buffer		NaAc Distilled Water	
	OD* (parts/part)	pH	OD* (parts/part)	pH	OD* (parts/part)	pH
0	0	6.2	0	7.0	0	7.4
2	0.57	7.2	0.54	8.6	0.55	8.9
5	0.73	7.2	0.68	8.6	0.76	9.0
7	0.77	7.2	0.75	8.6	0.77	9.1

* Oxygen demand—parts of oxygen per part of acetate.

of 0.1 part per part had been exerted, the pH at this point was 8.2 to 8.5, but subsequent oxidation proceeded at a different rate compared with the higher pH levels. In other words, in the time at which Δt was calculated the pH's of the cultures were essentially the same and thus the initial pH of 5.2 and 5.7 had a direct effect on the lag period and an indirect effect on the logarithmic oxidation rate. It is most likely that this indirect effect of initial pH on the oxidation rate was due to a selection of different bacterial species during the lag period.

At the present time there is no definite explanation of the reason for decreasing relative oxidation rate (parts of oxygen per part of substrate) with increasing acetate concentrations in contrast to the slight trend toward an increasing relative rate for propionate and butyrate. However, as has been shown, the amount of oxygen demand per part of fatty acid increases with increasing number of carbon atoms in the molecule. It can be reasonably assumed that the energy value is greater to the organisms as the concentration of substrate and length of the molecule increases. It is possible, therefore, that if a constant fraction of the higher energy output is directed to the construction of important intermediates in the oxidative pathways, then the combination of increasing concentrations and increasing energy yield may exert a stimulating effect on the oxidation rate. On the other hand, the possibility of a toxic effect with high acetate concentrations should not be disregarded.

It is also difficult to explain the mechanism of seed adaptation. Adaptation resulted in decreased lag periods and higher 5-day BOD values, but there was no significant corresponding increase in the oxidation rate during the logarithmic phase. The decrease in lag period is apparently affected somewhat by higher numbers of organisms but it has been shown that numbers of initial organisms in the seed is not the complete answer even when other environmental conditions are rigidly controlled. It is noteworthy that some sewage seeds used in these tests resulted in shorter lag periods and higher rates of oxidation than some adapted seeds even though all other environmental conditions were similar in each case. This may most likely be explained on the basis of the average generation time of the species mixture and differences in metabolic rate of different bacterial species in different seed sources.

In none of these tests was it possible to completely eliminate the lag period in the oxidation curves. This is particularly true with high substrate concentrations, but it is general knowledge that lag periods are also observed with very low substrate concentrations. Initial numbers of seed organisms have a minor role in affecting lag period. Generation time probably has a greater effect. But rather than consider numbers of organisms per se, it might be more lucrative to direct such investigations to a study of the relationships between food concentration and availability of important metabolic intermediates on a molecular basis. Biochemical reactions are subject to "mass action" laws as much as any chemical reaction. The citric acid cycle has been shown to be an important oxidative pathway for many bacterial species. In order for any carbon and energy source to enter into this pathway for subsequent oxidation and synthesis it must be converted by some means to acetate, which in turn enters the cycle through a condensation with oxalacetic acid to eventually form citric acid. The number of oxalacetic acid molecules present in a bacterial cell might thus become a very important limiting factor in the capacity of the cell to oxidize an organic substrate. Werkman and Wood (10) have shown that oxalacetic acid can

be formed through an enzymatic condensation of carbon dioxide and pyruvic acid.

In the Warburg tests described in this report, carbon dioxide was trapped in a potassium hydroxide vial in the Warburg flask in order to make direct oxygen uptake measurements. It would also be reasonable to assume that pyruvic acid was lacking since the principal supply of this compound is glycolysis and obviously no glycolysis was occurring with pure fatty acid substrates.

Thus, it is possible that the bacteria in the seed used in these tests were faced with a high food supply and a high oxalacetic acid requirement but with no carbon dioxide and/or pyruvic acid to satisfy this requirement for rapid oxidation in the lag period. This hypothesis is examined in the third phase of this study.

Summary and Conclusions

A study of the effects of substrate concentration, numbers of initial seed organisms, adaptation, and initial pH on the lag periods, rates of oxidation, and oxygen demand values of several of the lower fatty acids was made. The following conclusions are derived from the results of the tests.

1. Increasing concentrations of acetate, propionate, and butyrate resulted in an increasing absolute oxidation rate (mg/l oxygen uptake per unit time) after the lag period was over, but the length of the lag periods increased with increasing concentrations. Increasing concentrations of propionate and butyrate also resulted in a slightly increased relative oxidation rate (parts of oxygen per part of substrate per day).

2. No relationship was observed between length of lag periods and initial numbers of organisms in the sewage seed.

3. The initial pH values of 5.2 and 5.7 in these tests had marked effects on lag periods and oxidation rates and beyond this had no significant effect or definite trend.

4. Adaptation of seed has the effect of reducing the lag periods initially observed with sewage seed but does not significantly increase the logarithmic rate of oxidation. Through its effect of reducing the lag, more reliable short-term BOD values are obtained.

5. None of the factors studied had an effect on the ultimate (20-day) oxygen demand of a given substrate. However, all of these factors through their effect on lag period and oxidation did affect in one way or another the 5-day BOD values observed.

6. It was not possible to completely eliminate the lag periods observed with high fatty acid concentrations. Other factors, not previously considered, may affect the length of these lag periods.

C. CARBON BALANCE STUDIES

It has been shown (1) that, using adapted seed, the 5-day BOD values of the lower fatty acids represent approximately 70 per cent of the theoretical oxygen demand, based on complete combustion to carbon dioxide and water, and 91 per cent of the ultimate oxygen demand, based on direct measurement after 20 days' incubation. This means that the ultimate (20-day) oxygen demand represents approximately 75 per cent of the theoretical (or chemical) oxygen demand.

Prior to 1938 it was generally assumed that the conversion of relatively simple non-nitrogenous compounds by bacteria under highly aerobic conditions was limited to complete oxidation of the substrate to carbon dioxide and water. In support of this view, Krebs (11) had shown that the oxidation of acetate by *Escherichia coli* goes to com-

TABLE IX.—Carbonaceous Materials Balance for Oxidation of Acetate

Item	Amount	
Acetate conc. (mg/l)	1,000	10,000
Initial COD (mg/l)	1,035	10,500
Total BOD exerted (mg/l)	808	7,600
Final liquor COD (mg/l)	269	2,900
Filtrate COD (mg/l)	114	1,300
Cell fraction COD (mg/l)	155	1,600
Cell solids (mg)	140*	—
Portion of Original COD		
BOD (per cent)	78.0	72.3
Cells (per cent)	13.5–15.0	15.2
Residual† (per cent)	11.0	12.4
Total COD recovery (per cent)	102.5–104.0	99.9

* Cell solids.
† Biologically-unoxidizable organic material.

pletion at a quite constant rate and that essentially all of the acetate was oxidized.

Clifton and Logan (12) were unable to confirm Kreb's observations with their strain of *E. coli*. Over a pH range of 5.6 to 7.7 the rate of oxygen uptake remained at a relatively constant level irrespective of acetate concentrations ranging from 150 to 1,200 mg/l, until approximately 75 per cent of the oxygen required for complete oxidation had been consumed. At this time oxygen uptake decreased abruptly and approached a level near that of the control suspension to which no acetate had been added. The oxidation of propionate was also shown to proceed in a similar manner.

In another paper, Clifton (13) obtained 75 per cent of theoretical oxidation with acetate and butyrate using *Pseudomonas calso-acetica*. Clifton attributed the over-all reaction to be one of "oxidative assimilation" in order to account for the remaining 25 per cent not oxidized, meaning that 25 per cent of the original substrate was converted to new cellular protoplasm. A 25-per cent efficiency in cellular yield seemed to be extremely high since the commonly accepted figures are usually in the 8- to 15-per cent range reported by Porter (14).

Porges *et al.* (15) showed that C^{14}-containing residues (biologically unoxidizable) were formed during aerated sludge oxidation of C^{14}-labeled glucose and that this activity was associated with a residual COD. Symons and McKinney (16) contend that a non-nitrogenous polysaccharide is formed during activated sludge oxidation of acetate.

It was thus considered pertinent to this study to determine after oxidation the gross distribution of the carbonaceous material contained in the original substrate.

Experimental Methods

Experiments were conducted using 1,000-and 10,000-mg/l acetate and sewage seed. Chemical oxygen demand and suspended solids concentration were determined on the initial mixtures and the oxygen demand was measured manometrically until oxidation ceased. It previously was determined that the COD test, using silver sulfate as a catalyst, yields 100-per cent recovery of acetate. At that time the final liquors (collected from 10 replicate Warburg flasks) were passed through millipore filters that had been previously weighed. In the 1,000-mg/l test, the cells trapped on the filter were dried for 2 hr at 103°C and weighed in order to determine cell yield on a weight basis in addition to COD results. A second aliquot of cells was subjected to COD analysis in addition to COD determinations on the filtrate. Aliquots of the filtrates were also adjusted to pH 7.0 with weak sodium hydroxide and reseeded both with fresh settled sewage and with cells that had been grown on the original acetate in order to determine the susceptibility of the residual material to further oxidation. After seeding of this filtrate, manometric measurements were made

for an additional 33 days until it was established that no BOD material was present.

The results of these tests are presented in Table IX and show that it was possible to obtain a good carbonaceous balance. Distribution of the original substrate was as follows: 72 to 78 per cent was oxidized biologically, yielding CO_2 plus H_2O; 13 to 15 per cent converted to new cell protoplasm; and 11 to 12 per cent remained in the final liquor in the form of biologically-unoxidizable organic material (residue COD).

In addition to the BOD and COD results, an organic nitrogen analysis was made on the millipore filtrate in the 1,000-mg/l test. This filtrate contained 8.0 mg/l organic nitrogen, which represented approximately 7 per cent of the weight of the residual organic material.

Discussion

The oxygen demand values obtained from these investigations are comparable with preliminary results (1), and with those of others (12)(13). The amount of cellular yield is comparable with the generally accepted value of 8 to 15 per cent (14).

Until recently, little attention has been given to the possibility of by-product formation during oxidation of relatively simple organic substrates, especially with regard to the possible biological unoxidizability of such by-products. Where their production has been recognized, it has been the tendency to label them as "humus."

It seems imperative to determine what this residual organic matter actually consists of, whether or not similar material is produced during oxidation of other substrates in BOD tests or in waste treatment processes, and to evaluate the possible danger of the persistence of low concentrations in streams receiving effluents containing the material.

Summary and Conclusions

A carbonaceous balance has been obtained subsequent to oxidation of 1,000- and 10,000-mg/l acetate in order to determine the gross distribution of the original substrate. The distribution was as follows: 72 to 78 per cent oxidized biologically to CO_2 plus H_2O; 13 to 15 per cent converted to new cell protoplasm; and 11 to 12 per cent remaining in the final liquor (millipore filtrate) in the form of biologically unoxidizable organic material. The concentration of organic nitrogen associated with this residual COD represented approximately 7 per cent of the weight of the material.

Acknowledgment

This study was supported by a grant from the Division of Research Grants, National Institutes of Health, U. S. Public Health Service, Washington, D. C.

References

1. Gaffney, P. E., and Heukelekian, H., "Oxygen Demand of the Lower Fatty Acids." *Sewage and Industrial Wastes*, **30**, 5, 673 (May 1958).
2. Gaffney, P. E., and Heukelekian, H., "Oxygen Demand Measurement Errors in Pure Organic Compounds—Nitrification Studies." *Sewage and Industrial Wastes*, **30**, 4, 503 (Apr. 1958).
3. Moore, E., Thomas, H. A., and Snow, W. B., "Simplified Method for Analysis of B.O.D. Data." *Sewage and Industrial Wastes*, **22**, 10, 1343 (Oct. 1950).
4. Ruchhoft, C. C., Placak, O. R., and Ettinger, M. B., "Correction of B.O.D. Velocity Constants for Nitrification." *Sewage Works Jour.*, **20**, 5, 832 (May 1948).
5. Orford, H. E., "Deoxygenation of Sewage—A Critical Examination and New Mathematical Formulation." Thesis, New York Univ., New York (1952).
6. Balmat, J. L., "Chemical Composition and Biological Oxidation of Particulate Fractions in Domestic Sewage." Thesis, Rutgers Univ., New Brunswick, N. J. (1955).

7. Rhame, G. A., "A Two-Point Method for Estimation of First-Stage B.O.D." *Sewage and Industrial Wastes*, **28**, 9, 1087 (Sept. 1956).
8. Orford, H. E., Rand, M. C., and Gellman, I., "A Single Dilution Technique for B.O.D. Studies." *Sewage and Industrial Wastes*, **25**, 3, 283 (Mar. 1953).
9. "Standard Methods for the Examination of Water, Sewage, and Industrial Wastes." 10th Ed., Amer. Pub. Health Assn., New York (1955).
10. Werkman, C. H., and Wood, H. G., "Heterotrophic Assimilation of Carbon Dioxide." *Advances in Enzymol.*, **2**, 135 (1942).
11. Krebs, H. A., "The Role of Fumarate in the Respiration of *Bacterium coli commune*," *Biochem. Jour.*, **31**, 2095 (1937).
12. Clifton, C. E., and Logan, W. A., "On the Relation Between Assimilation and Respiration in Suspensions and in Cultures of *Escherichia coli*." *Jour. Bacteriol.*, **37**, 523 (1939).
13. Clifton, C. E., "On the Possibility of Preventing Assimilation in Respiring Cells." *Enzymologia*, **4**, 246 (1937).
14. Porter, J. R., "Bacterial Chemistry and Physiology." John Wiley and Sons, Inc., New York (1946).
15. Porges, N., Wasserman, A. E., Hopkins, W. J., and Jasewicz, L. "Oxidation of Radioactive Glucose by Aerated Sludge." *Proc. 13th Ind. Waste Conf.*, Purdue Univ., Ext. Ser. **96**, 512 (1959).
16. Symons, J. M., and McKinney, R. E., "The Biochemistry of Nitrogen in the Synthesis of Activated Sludge." *Sewage and Industrial Wastes*, **30**, 7, 874 (July 1958).

CHIEF CHEMIST NEEDED IN WINNIPEG

The Waterworks and Waste Disposal Division of The Metropolitan Corporation of Greater Winnipeg (Manitoba) needs a Chief Chemist to head and organize a new branch of the Division to be known as Research and Laboratory Control.

The Chief Chemist will be responsible for research projects dealing with water supply and sewage disposal, quality of the water supply, quality control of sewage treatment facilities, analysis of industrial waste samples, river pollution control, odor control, and quality control of purchased materials.

The applicant should be a graduate in chemistry or chemical engineering with post graduate experience in sanitary engineering, part of which should have been in a position of responsibility in research and/or operation of water supply and sewage treatment facilities.

Liberal fringe benefits are included. Salary is open and will be commensurate with qualifications and experience.

Applications should be forwarded to: Personnel Manager, Personnel Dept., 10 Fort Street, Winnipeg 1, Manitoba.

IMPROVED DIGESTER PERFORMANCE THROUGH MIXING

H. V. Myers, Jr.

Original Sludge Digestion Operation

The wastewater treatment plant in the City of Pontiac, Michigan, has two digesters. Prior to Dec. 1959 they were used in parallel when both were in operation. Both digesters, constructed of reinforced concrete, are 75 ft in diam and have 26-ft side walls with a 32-ft depth at the cone. Both have internal hot-water heating coils. The older of the two digesters is of the floating cover type and has no provision for mixing. For many years this digester was the only one in operation and problems of high solids in the supernatant, unreliable gas production, and varying temperatures existed. The other digester has a fixed cover and is now equipped with a gas recirculation unit. In Dec. 1959 after the gas recirculation unit was added the operation was changed to a two-stage digestion system.

Modifications

The fixed cover digester is used as the primary. It has a rectangular gas collector 3 ft high by 3 ft wide across the diameter of the top. The fixed cover is supported by four concrete beams resting on concrete columns. These beams, which project into the sludge, increased the possibility for scum formation in these sections.

A transfer sludge well was constructed near the digester with piping to draw sludge from the cone of the digester through a telescoping valve. From the well the sludge can flow, by gravity, to the second digester, the drying beds, or the lagoon.

At the same time a gas recirculation unit was installed on top of the gas collector. The purpose of this unit was to aid in mixing the contents of the digester; the following results were expected: (*a*) there would be little or no scum formation, (*b*) the raw sludge would be better mixed with the seed sludge, and (*c*) there would be a more effective heat transfer from the heating coils.

The selection of the gas mixing equipment was influenced by the physical structure of the digester. By using multiple discharge points, so that each section of the digester could be mixed, it was believed that effective scum control could be realized. The equipment consisted of a 150-cfm compressor, time clock-operated controls, nine gas wells, eight peripherally and one centrally located, all discharging at the 15-ft depth. The gas is collected, piped to a compressor, and delivered by means of an automatic sequence to each peripheral well for a selected time (usually 20 min). The center gas well is controlled manually.

Modified Sludge Digestion Operation

The work on the primary digester was completed and put into operation in Dec. 1959. This was done by using seed sludge from the floating-cover digester. In a few days the digester began to produce gas and after a few more days all raw sludge was pumped to the primary digester and the float-

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TABLE I.—Primary Digester Solids Data

Date	Depth (ft)	Solids (%)	Volatile Solids (%)
1960			
Jan. 29	10	.9	50
↓	26	.5	75
Feb. 3	10	.2	—
19	32	4.5	50
Mar. 3	8	1.3	58
↓	13	1.3	42
22	5	1.6	—
	10	2.0	—
	15	2.1	—
	20	2.0	—
↓	28	5.4	—
July 18	9	1.3	60
	14	3.2	50
	19	1.8	44
	24	1.6	43
↓	29	9.4	66
1961			
Jan. 16	10	5.3	53
	15	5.5	54
	25	5.8	59
↓	30	5.8	49
Mar. 22	10	3.1	50
	15	3.1	50
	20	3.1	49
	25	3.1	48
	30	5.7	42
↓	32	5.9	40
May 11	5	3.8	56
	10	3.6	56
	15	3.9	56
	20	4.0	50
↓	25	5.8	47

ing-cover digester became the secondary digester. In Jan. 1960 the gas production dropped from 30,000 cfd to 6 to 8,000 cfd in the primary digester, while the total gas production dropped only slightly. After sampling, in the primary digester, it was found that there was a low solids content as shown in Table I. The solids were apparently settling to the bottom shortly after they entered and had no chance to digest before being transferred to the secondary digester.

Additional Changes

The center gas well was lengthened to 28 ft and all peripheral wells to 21 ft, but this did not seem to improve the solids distribution. Also, during this period, digested sludge was recirculated and neither of these actions seemed to increase the solids concentration. The removal of supernatant from the primary digester helped increase the solids concentration and the gas production rose. The removal of the clear supernatant from the primary digester became a daily task in order to increase the solids concentration.

In Sept. and Oct. 1960 additional piping changes were made. The raw sludge application point was lowered, a supernatant overflow pipe was added, and another sludge withdrawal pipe was added. The digester was put back into operation and the resulting solids distribution was improved as is shown in Table I.

Present Sludge Digestion Operation

The present operation can be described as follows: Raw sludge with approximately 4-to 5-per cent solids (50-to 55-per cent volatile) is added to the primary digester. Using the supernatant overflow, transfer sludge with 3-to 4-per cent solids (45- to 50-per cent volatile) is withdrawn to the secondary digester which has a sludge drawoff at the cone nadir and supernatant drawoffs at various depths. Supernatant from the secondary digester has 0.2-to 0.4-per cent solids (50-per cent volatile) and digested sludge has 8- to 9-per cent solids (35- to 45-per cent volatile). About 95 per cent of the gas is produced in the primary digester indicating that digestion is essentially completed here. The per cent solids in the secondary supernatant has fallen sharply and the gas produced per pound of volatile solids is more consistent than found in the previous method. The loading of the

digesters is in the range of 40 to 50 lb volatile solids per 1,000 cu ft of tank. The detention time is 25 to 30 days. During 1960 the average temperature of the primary digester was 85°F with a maximum of 96°F and a minimum of 78°F. When the primary digester was dewatered in Sept. 1960 little scum was evidenced. Samples taken in May 1961, after 7 months of operation, show no significant scum formations.

Summary

It has been found that mixing of the digester contents has inhibited scum formation, improved heat transfer, and gives a stable digestion process at the loading rates and detention times covered in this study.

MEETINGS OF INTEREST

1961

Nov. 13–17 **American Public Health Association,** Cobo Hall, Detroit, Mich. APHA, 1790 Broadway, New York 19.

Nov. 21 **11th Semiannual Meeting and Midyear Conference of the Manufacturing Chemists Assn., Inc.,** New York, N. Y. MCA, 1825 Connecticut Ave., N.W., Washington 9, D. C.

Nov. 26–Dec. 1 **American Society of Mechanical Engineers,** Winter Annual Meeting, Statler Hilton Hotel, New York. ASME, 345 East 47th St., New York 17.

Nov. 26–Dec. 1 **28th Exposition of Chemical Industries,** Coliseum, New York, N. Y.

Nov. 30–Dec. 2 **National Municipal League,** Fontainbleau Hotel, Miami, Fla.

Dec. 3–6 **American Institute of Chemical Engineers,** Hotel Commodore, New York, N. Y. F. J. Van Antwerpen, 25 West 45th St., New York 36.

Dec. 26–31 **American Association for the Advancement of Science, Denver, Colo.**

1962

Feb. 13–14 **Fourth Sanitary Engineering Conference** (Subject: Water Distribution Systems), University of Illinois, Urbana, Ill. Professor Ben B. Ewing, Department of Civil Engineering, University of Illinois; or C. W. Klassen, Chief Sanitary Engineer, Department of Public Health, Springfield, Ill.

Apr. 19–20 **Eleventh Southern Municipal and Industrial Waste Conference,** University of North Carolina, Chapel Hill, N. C. Dept. of Sanitary Engineering, University of North Carolina, Box 899, Chapel, N. C.

THE SIGNIFICANCE OF TRACE ORGANICS IN WATER POLLUTION

O. J. Sproul and D. W. Ryckman

There are many important reasons for real concern about trace organics in domestic water supplies. These pollutants manifest themselves in several ways. Taste and odor problems associated with these organics in waters are well known. In addition, consumers may be exposed to undesirable physiological hazards from continued consumption of water with certain organic pollutants (1). The toxicity of certain organics to fish life has been well demonstrated. Various other undesirable effects of organics in water can be noted, including among others, organic chemical fouling of ion exchange resins, malodors produced in the beverage industry, and difficulties in metal plating baths.

Various sources of organic chemical pollutants have been discussed in a qualitative manner. Industrial discharges from oil refineries and paint and varnish manufacturing, among others have been implicated in taste and odor problems in water supplies (2). Oil refinery effluents have been implicated as a source of carcinogenic chemicals when carbon filter adsorbates were tested on the skin of mice (3). Decaying vegetation can give rise to taste and odor problems in waters. Phenolic compounds have been reported to be present in tree leaf infusions (4). Odorous substances which may be readily detected at a very high dilution are contributed by certain microorganisms (5).

At the time this work was done O. J. Sproul was Research Fellow in Environmental and Sanitary Engineering, Washington University, St. Louis, Mo. He now is in the Department of Civil Engineering at the University of Maine, Orono, Me. D. W. Ryckman is Director of Environmental and Sanitary Engineering at Washington University.

The paper was presented at the American Chemical Society Meeting in St. Louis, Mo., March 29, 1961.

Objectives

Specific information on the chemical and biochemical characteristics of trace organic pollutants of domestic water supplies is very limited. Further, data on the physiological characteristics of these pollutants is also not available.

This work was initiated to determine both the significant characteristics and origin of these organic pollutants. Data on the studies of these organics will be presented. These data will include quantities of organics by source, chemical and biochemical oxidation, and odor characteristics.

Method of Study

A consideration of organic chemical pollutants will show that there are four general sources of pollutants: (*a*) industrial wastes, (*b*) domestic sewage, (*c*) natural runoff, and (*d*) compounds produced by microorganisms. The sampling program included all of these sources. Samples were taken from a river above, below, and at a distant site from a large metropolitan area. Natural organics were obtained by sampling a stream tributary to the above river which had no pollution entering it except that from agricultural runoff and decaying vegetation. The domestic sewage sample was obtained from a site which had only

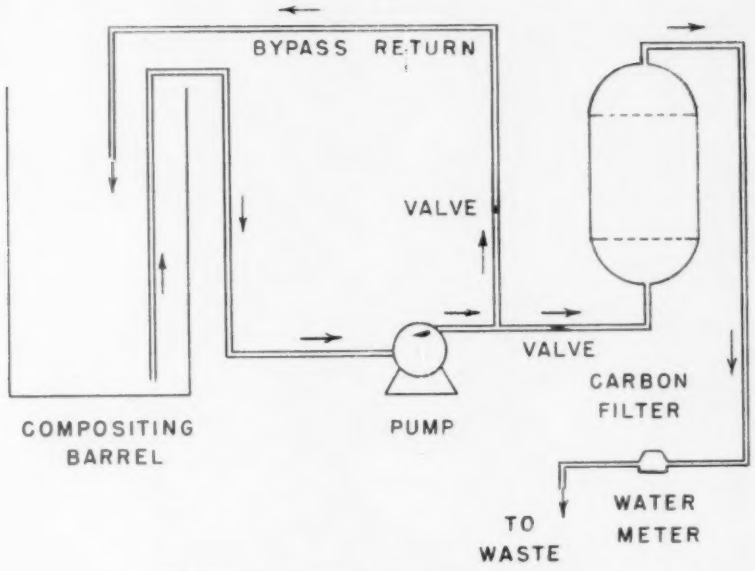

FIGURE 1.—Layout for wastewater sampling.

domestic wastes from single family dwellings tributary to it.

Sampling Procedures

The industrial samples were obtained from representative industrial effluents. Considerations made in the selection of the industries were as follows: (*a*) prior work indicated an organic pollution problem associated with the industry, (*b*) wastes were of possible physiological significance, and (*c*) a spectrum of industrial contamination was desired. An industry usually thought of as an inorganic one was included for comparative purposes. The types of industrial effluents sampled were brewery, chemical, corn refining, meat packing, metal fabrication, paint, pharmaceutical, refinery, and soap.

The diversity of the pharmaceutical and chemical industries from one plant to another should be considered in the interpretation of the results.

The organic pollutants were captured from the water being sampled by the carbon filter technique (6). Carbon filters of 1.3- and 2.0-cu ft capacity were used in these studies.

The physical setup generally used for the industrial and domestic waste samples is shown in Figure 1. The waste was placed in the compositing barrel as it was collected. When a sufficiently large volume had been collected, the pump was started and the by-pass valves regulated so that a satisfactory rate of flow through the carbon was obtained. The by-passed flow was returned to the barrel and was then recycled. The water after flowing through the carbon, which removed the organic pollutants, was then wasted to the sewer. The sampling program for the corn refining industry was such as to obviate the use of the barrel and the pump. Here, the influent to the carbon filter with the regulating valves as shown was piped directly from the pressure discharge sewers. The pressure in the sewer was used to push the waste through the carbon. The sampling

program at the metal fabrication industry was such that the suction side of the pump was placed directly in the waste stream and the proper flow obtained by regulating the valves.

The samples taken from each industrial and domestic waste source were composited throughout a normal day so as to obtain organics which would be typical of that site. The flows throughout the first day were gaged either by weirs, current meters, or in-plant recording meters on the discharge sewers. The second day flows were again gaged and the samples taken at each interval were then composited according to the previously measured flow.

The pH of all samples taken was adjusted where required to gve a pH which fell in the range 7.0 to 7.5 since it has been shown that activated carbon adsorptive efficiencies have reduced values at a pH of 8.5 or higher (7). Where the pH of the sample was in this range or was lower, no adjustment was made. The rate of flow through the carbon filter was adjusted to about one gallon per minute for the more polluted samples and up to four gallons per minute for the less polluted.

The organic pollutants were adsorbed from the river and stream samples in a similar way. The flow through the filter was such as to produce a rate of 2,500 to 4,000 gpd/cu ft in the filter. The carbon was changed weekly. A sand filter was placed ahead of the carbon filter to remove heavier sand particles. A pre-sedimentation tank was installed ahead of the sand filter at the river site above the metropolitan area. This tank was a 55-gal barrel and gave a sufficient detention period so as to allow a more reasonable length of time between backwashing of the sand filter. The apparatus at the river and stream sites consisted of a closed system and all units making up these installations were under pressure when operating.

Sample Processing

The carbon after removal from the filter was processed to elute the adsorbed organics. The carbon was first dried (below 45°C) to remove the moisture and then eluted with suitable solvents. The solvents were then removed and the organic pollutants dried with a stream of air below the boiling points of the solvents and the organics weighed.

A solvent system was selected which would elute from the carbon filter the major portion of the adsorbed organics. Chloroform and ethyl alcohol were selected for the extraction procedure. These were selected since they have been shown, of the usually used solvents, to remove the major part of the adsorbed organic material (6). An initial separation of materials during the extraction was obtained by first extracting with the chloroform, drying the carbon, and then extracting again with the alcohol. This allowed an initial separation of the materials into the more odorous fraction by the chloroform and a less odorous, more polar fraction, by the alcohol (6). Additional considerations also indicated the use of this system since it has been reported that fresh pollution gives rise to an initially higher chloroform fraction (8). Physiological studies should be made so as to evaluate synergistic effects of the total organic extract. The combined chloroform and alcohol extracts were used in these studies to represent the total organic fraction.

The degree of importance of any particular source of organic pollution should be related to its ability to give rise to undesirable conditions at the point where water containing the wastes from the source will be used. This is directly related to the ability of the stream to assimilate the organics and render them innocuous. Simulated stream condition studies were made in the laboratory using the two bottle single-stage dilution technique and a 5-mg/l solution of organics (9). Oxy-

gen determinations were made daily. Nitrite determinations were made to determine the point at which nitrification started and to assure that BOD values obtained were due only to oxidation of carbonaceous materials. Chemical oxidation demand data, to obtain a measure of the extent of biological oxidation, were obtained by the dichromate reflux method (10).

The ability of these trace organic chemicals to create odor problems was measured by the threshold odor determination (10). Determinations were made on both the unaltered organics and on the organics which had been degraded biologically by the simulated stream conditions. The concentrations at which odor was first detectable in the samples after addition of the sewage seed were determined at the start of oxidation. The odor of the same samples after 10 days of incubation were determined so that a before and after comparison of detectable odor concentration could be made. Odor data were determined on the blank used in the BOD test to allow an evaluation of the contributory effect of the added sewage seed. The changes in odors were compared by obtaining the per cent change of the detectable odor concentrations during the incubation period. This was computed by dividing the difference between the beginning and ending detectable odor concentrations by the smaller of the two values.

Results and Discussion

Concentration of Pollutants

The concentration of extractable organic material from each of the sources sampled is presented in Table I. The concentrations from the lowest to the highest varied by factors of 414 for the chloroform fraction, 77 for the alcohol fraction, and 85 for the total fraction. Of the industrial samples the soap sample yielded the greatest quantity of total organics and the corn refining sample the least. Only the soap and chemical samples had chloroform extract concentrations greater than the alcohol extracts. The inorganic industry represented by the metal fabrication sample had a significant amount of extractable material in its waste. In the assessment of the relative contribution which any industry makes to the over-all organic chemical pollution load the amount of material which inorganic industries contribute should be considered.

TABLE I.—Concentration of Organic Pollutants

Source	Chloroform Soluble (mg/l)	Alcohol Soluble (mg/l)	Total (mg/l)
Industry			
Brewery	11	110	120
Chemical	300	140	440
Corn refining	1.4	6.0	7.4
Meat packing	110	400	510
Metal fabrication	2.5	5.2	7.7
Paint	27	71	98
Pharmaceutical	3.0	7.6	11
Refinery	66	320	390
Soap	580	52	630
Domestic	16	48	64
River			
Above city	0.11	0.28	0.39
Below city	0.12	0.33	0.45
Distant from city	0.062	0.23	0.29
Unpolluted stream	0.098	0.23	0.33

The river and unpolluted stream samples all contained significant amounts of both chloroform and alcohol extractable fractions. In regard to the river samples the site directly below the metropolitan area had the largest quantity of recovered material. The site above this metropolitan area had only about 13 per cent less total extractable material which was indicative of pollution of the river above this area. The ability of the river to remove extractable material was indicated by the lower concentration of total organics at the site distant from the metropolitan area. The total organic load here was only 64 per cent of what it was just below the area. Chlo-

roform and alcohol fractions both showed a decrease at the distant site. The unpolluted stream contributed a significant quantity of extractable material. The quantity of chloroform soluble material approached that above and below the metropolitan area but the alcohol fraction was less.

Detectable Odor Concentration

The detectable odor concentrations of the samples are presented in Table II. None of the samples were found to be odor free. Among the industrial and domestic chloroform extracts the chemical and refinery samples had the greatest potential for odor. The most odorous of the chloroform soluble extracts was 228 times as odorous as the least, while the ratio for the total organics was 128. In all cases, as seen in Table II, the concentrations of chloroform extracts to produce detectable odors were less than those for the total extracts. This confirms the fact that the chloroform fraction contains the major taste and odor causing compounds and thus are referred to as having the greatest odor potential.

TABLE II.—Odor Potential of Organic Pollutants

Source	Concentration Required for Detectable Odor	
	Chloroform Soluble Organics (ppb)	Total Organics (ppb)
Industry		
Brewery	770	1,400
Chemical	28	32
Corn refining	1,000	3,600
Meat packing	1,200	3,600
Metal fabrication	890	1,600
Paint	390	1,000
Pharmaceutical	290	340
Refinery	84	510
Soap	900	1,800
Domestic	590	1,800
River		
Above city	290	190
Below city	220	190
Distant from city	48	110
Unpolluted stream	220	390

The domestic waste was somewhere between the most and the least odorous of the waste samples.

The odor panel members associated the odors with the industry for such samples as the brewery, chemical, and refinery organics. This was especially noted for those panel members who could detect the odor at higher dilutions. For many of the other organic samples the panel members did not associate the odor with the corresponding industry.

The river and stream extracts generally had a higher potential (per unit weight of extract) for causing odor than the waste samples. The major exception to this was the chemical industry. Above the metropolitan area the total organic extract was definitely more odorous than the chloroform fraction. This may be caused by synergistic effects between the chloroform and alcohol fractions.

The unpolluted stream chloroform fraction had about the same potential for odor (per unit weight of extract) as the river organics above and below the metropolitan area, whereas the total organic odor was definitely higher for the unpolluted stream. This difference may be attributed to several things. It may be caused by the industrial and domestic pollution present in the river, alteration of the natural organics into more odorous compounds in the river, or a combination of both.

The greatest potential for odor among the river sample extract occurred at the site distant from the metropolitan area. Per unit weight of extract, the chloroform fraction showed a fivefold increase in ability to cause odor at the downstream station over that at the upstream points. The same comparison on the total organic fractions showed an increase of about twofold. The alteration of the organic fractions while flowing down the river increased their capacity to cause odor on a unit weight basis.

The dilution required to reduce the

TABLE III.—Dilution to Reduce Odor to a Barely Perceptible Level

Source	Dilution Factor	
	Chloroform Soluble Organics	Total Organics
Industry		
Brewery	14	86
Chemical	11,000	14,000
Corn refining	1.4	2.1
Meat packing	92	140
Metal fabrication	2.8	4.8
Paint	69	98
Pharmaceutical	10	32
Refinery	780	760
Soap	640	350
Domestic	27	36
River		
Above city	—	2.0
Below city	—	2.4
Distant from city	1.3	2.6
Unpolluted stream	—	—

odor to a level at which it was just detectable is shown in Table III. The dilution factors shown, which are functions of both the quantity of the odor causing material and its ability to cause odor, were obtained from data in Tables I and II.

Among the waste samples shown in Table III, the highest dilution factor was 7,500 times as high as the lowest for the chloroform fraction and 6,700 times for the total fraction. The importance of corrective measures to reduce odor potential is indicated for those industries which are large consumers of water and which have high dilution requirements.

The importance of considering the total fraction rather than the chloroform fraction alone was indicated for all wastes except the soap industry. This was because of the generally larger quantities of alcohol-soluble than chloroform-soluble material.

It may be seen from Table III that dilution factors of 2.0 to 2.6 were obtained for the river water samples. Thus, if such river sites are to be used as a source of domestic water, difficulties with odor problems might be predicted since dilution was indicated as necessary to overcome the odor in the river water at these sources.

Oxygen Demand

The chemical oxygen demands of the extracted organics are presented in Table IV. The COD of all the chloroform extracts were generally of the same order of magnitude. The lower COD in the unpolluted stream chloroform fraction may have been caused by complex compounds which were more resistant to oxidation by this test. The alcohol fraction COD's were significantly less than those of the chloroform fractions. The values for the alcohol extractables show less similarity than the chloroform extractables.

Microchemical analysis of the river and unpolluted stream alcohol fractions revealed ash contents in these samples of from 11 to 20 times those of the chloroform fractions. The carbon and hydrogen in the alcohol fractions were significantly less than the chloroform fractions. The higher ash and correspondingly lower carbon and hydrogen is one explanation for the lower

TABLE IV.—Chemical Oxygen Demand of Organic Pollutants

Source	Measured COD of 5-mg/l Solution		COD of 5-mg/l Solution of Extracted Organics (mg/l)
	Chloroform (mg/l)	Alcohol (mg/l)	
Industry			
Brewery	12.0	4.53	5.20
Chemical	8.26	4.40	7.04
Corn refining	10.7	4.85	5.96
Meat packing	12.9	1.16	3.69
Metal fabrication	12.0	2.56	5.63
Paint	10.0	6.48	7.45
Pharmaceutical	11.4	2.27	4.85
Refinery	12.0	1.47	3.27
Soap	12.9	4.64	12.2
Domestic	10.3	2.05	4.12
River			
Above city	9.90	6.35	7.34
Below city	9.21	4.81	5.98
Distant from city	11.3	6.14	7.26
Unpolluted stream	7.83	4.93	5.80

COD values obtained on alcohol fractions.

A graphical presentation of the biological oxidation of the samples is presented in Figures 2 and 3. The nature of the utilization of oxygen in

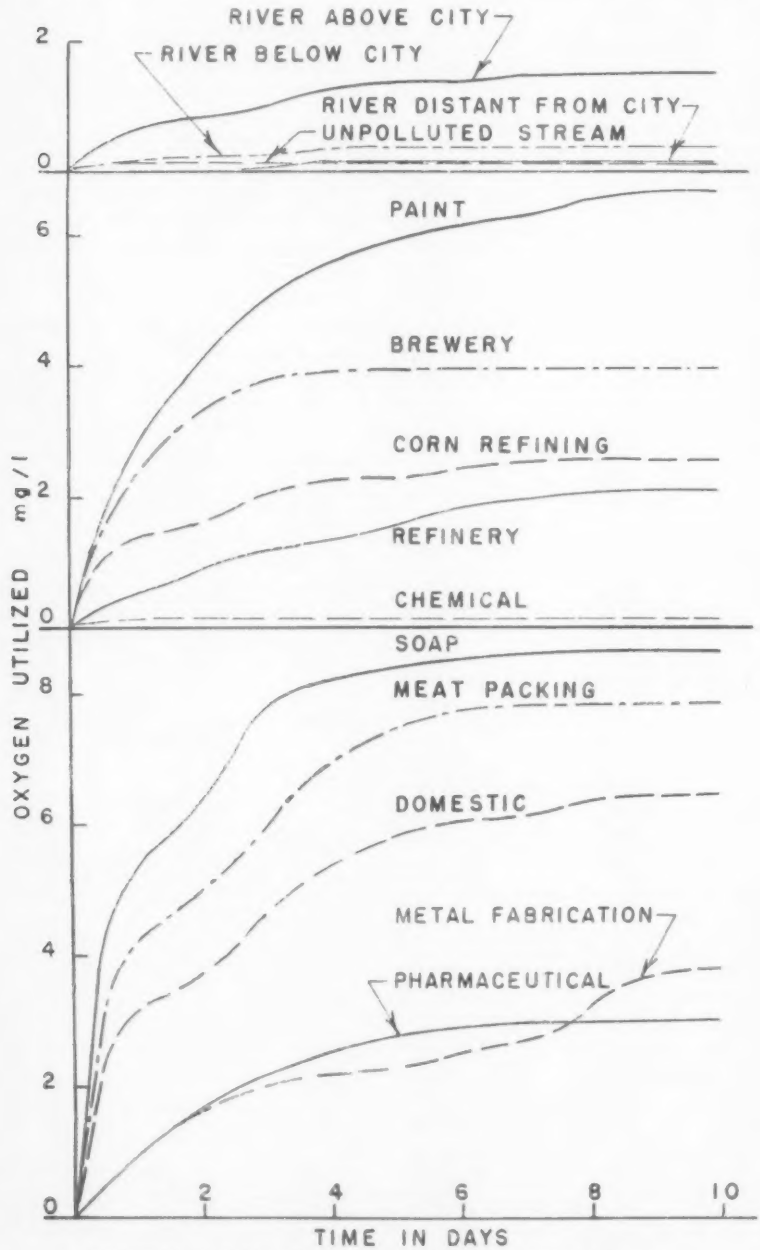

FIGURE 2.—BOD progression of chloroform-soluble organics.

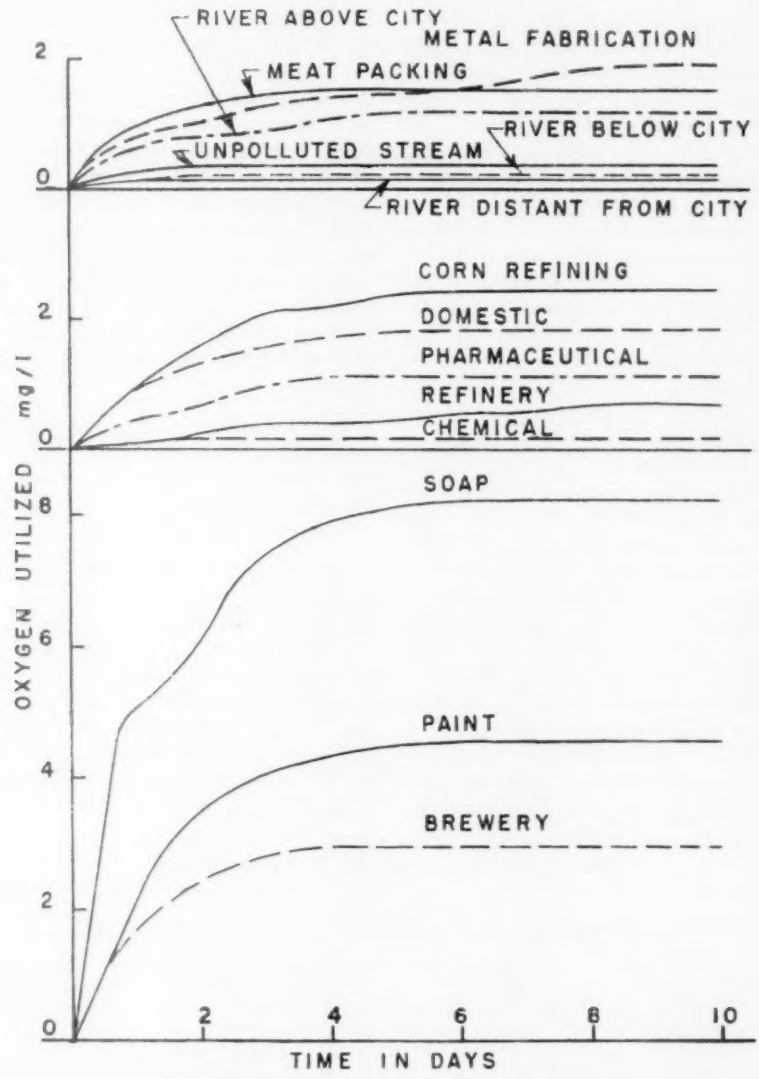

FIGURE 3.—BOD progression of total organics.

substrates of 5 mg/l extract material, as indicated by the shape of the curves in both the chloroform and total fractions, was essentially the same for each particular sample. Exceptions were the chemical, river samples below the metropolitan area, and unpolluted stream samples which showed a marked resistance to biological degradation in both the chloroform and total organic fractions. There was no pronounced lag period in oxygen utilization indicating that an initial acclimatizing period was not required before oxidation of the organics.

The curves for corn refining, metal fabrication, refinery, and the river sample above the metropolitan area

showed some acclimatizing to secondary oxidation products. This is indicated in both figures by decreases in the slopes of the curves and then subsequent increases in the slopes. In lesser degree this same acclimatizing was also displayed by the soap, meat packing, and domestic waste chloroform extracts in Figure 2 and the soap total organic fraction in Figure 3.

Information on the oxidation of the samples was obtained for a 20-day period. No significant increase in the oxidation of the carbonaceous portion of the organics was observed after 10 days. All of the samples showed nitrification between 10 and 20 days.

A comparison of the 5-day BOD and the corresponding COD for each sample is presented in Table V. The river and stream samples and some waste samples were resistant to biological degradation (BOD less than 15 per cent of COD). Of the chloroform organics only the domestic, meat packing, paint, and soap samples were sufficiently oxidized biologically to class them as easily oxidizable materials. In the total organic fraction only the brewery, paint, and soap samples show ease of oxidation. The corn refining, meat packing, and domestic total organics were oxidized biologically to an intermediate degree.

Certain samples exhibited a greater and others a lesser degree of oxidation when the chloroform and total fractions are compared. The brewery, corn refining, and metal fabrication total fractions underwent significantly higher degrees of oxidation. The meat packing and domestic samples were not oxidized as extensively in the total fraction. A higher total organic fraction oxidation may indicate the following:

1. A greater percentage of the alcohol fraction was more readily available for biological oxidation than the chloroform soluble.
2. Synergistic effects.

The change in the threshold odor by biological oxidation is presented in Tables VI and VII. Evaluation of this data requires consideration of the effect of the sewage seed on the odor change. The control samples containing sewage seed blank increased in odor during the incubation. The effects of the sewage seed on the odor change of any sample, however, is comparable

TABLE V.—Biochemical Oxidation of Organic Pollutants

Source	Chloroform Soluble		Total Organics	
	5-day BOD of 5-mg/l Solution (mg/l)	BOD as % of COD	5-day BOD of 5-mg/l Solution (mg/l)	BOD as % of COD
Industry				
Brewery	3.90	32	2.92	56
Chemical	0.10	1	0.15	2
Corn refining	2.27	21	2.35	39
Meat packing	7.47	58	1.48	40
Metal fabrication	2.28	19	1.42	25
Paint	5.87	59	4.40	59
Pharmaceutical	2.76	24	1.05	22
Refinery	1.67	14	0.44	13
Soap	8.34	65	8.05	66
Domestic	5.84	56	1.78	43
River				
Above city	1.35	14	1.13	15
Below city	0.37	4	0.20	3
Distant from city	0.16	1	0.14	2
Unpolluted stream	0.12	2	0.37	6

TABLE VI.—Odor Change by Simulated Biological Stream Conditions

Sample	Detectable Odor Concentration Before Incubation (5 mg/l of Sample) (ppb)		Detectable Odor Concentration After 10 Days Incubation (ppb)		Change in D.O.C.* as % of Smaller D.O.C. (+ is increase in odor, − is decrease)	
	Chloroform Soluble	Total Organics	Chloroform Soluble	Total Organics	Chloroform Soluble	Total Organics
Blank	2,200		900		+140	
Glucose (5 mg/l)	3,000		1,400		+110	
Industry						
Brewery	710	1,200	940	940	−32	+28
Chemical	9.8	9.8	17	26	−73	−160
Corn refining	180	540	360	620	−100	−15
Meat packing	470	940	710	620	−51	+52
Metal fabrication	470	470	470	1,200	0	−150
Paint	120	710	820	940	−580	−32
Pharmaceutical	240	710	310	620	−29	+15
Refinery	78	470	100	360	−28	+31
Soap	2,500	1,800	2,200	620	+14	+190
Domestic	200	470	940	360	−370	+31

* Detectable Odor Concentration.

to the effects of a natural water course on the sample and thus this test procedure measures what is desired.

The odor may either increase or decrease during biological oxidation. All of the chloroform soluble organics exhibited a decrease in the odor potential except the soap sample, which had a minor increase. The paint and domestic sewage chloroform fractions had significant decreases in potential odor. The total fraction indicated less similarity in odor change. Six of the 10 waste samples increased and the rest decreased in odor.

Conclusions

1. The carbon filter technique with pH adjustment of the waste was used successfully to extract organic pollutants from liquid wastes.

TABLE VII.—Odor Change by Simulated Biological Stream Conditions

Sample	Detectable Odor Concentration Before Incubation (5 mg/l of Sample) (ppb)		Detectable Odor Concentration After 10 Days Incubation (ppb)		Change in D.O.C.* as % of Smaller D.O.C. (+ is increase in odor, − is decrease)	
	Chloroform Soluble	Total Organics	Chloroform Soluble	Total Organics	Chloroform Soluble	Total Organics
Blank	2,200		900		+140	
Glucose (5 mg/l)	3,000		1,400		+110	
River						
Above city	310	160	710	1,100	−130	−590
Below city	310	830	550	1,100	−77	−34
Distant below city	410	68	410	470	0	−590
Unpolluted stream	230	410	240	820	−4	−100

* Detectable Odor Concentration.

2. All of the sources sampled yielded a significant amount (ranging from 7.4 to 630 mg/l of total organics) of chloroform- and alcohol-soluble extractable material. The alcohol fraction of the waste sample was generally greater than the chloroform fraction.

3. Biological degradation occurred in varying degrees (ranging from 2 to 66 per cent of measured COD) in all samples. The chemical, refinery, river, and unpolluted stream samples showed the greatest resistance to biological oxidation.

4. All organics extracted had a significant odor potential. The dilution required to give a minimum perceptible odor varied from 2 to 14,000 fold.

5. Odor potential per unit weight of extracted material of the total organic fraction may be either increased or decreased by biological oxidation in streams, depending on the particular type of organics.

Acknowledgments

This investigation was supported in part by the National Institutes of Health Research Grant No. RG-6154 and National Institute of Allergy and Infectious Diseases Fellowship No. EF-10,730, United States Public Health Service.

The assistance and cooperation of personnel from the many industries, public water supply departments, companies, and the Robert A. Taft Sanitary Engineering Center are gratefully acknowledged.

References

1. Hueper, W. C., "Cancer Hazards from Natural and Artificial Water Pollutants." Proceedings, at Conference on Physiological Aspects of Water Quality, Washington, D. C., 181, Sept. 8–9, 1960.
2. Hartung, H. O., "Taste and Odor." *Jour. Amer. Water Works Assn.*, **52**, 11, 1363 (Nov. 1960).
3. Hueper, W. C., and Ruehhoft, C. C., Carcinogenic Studies on Adsorbates of Industrially Polluted Raw and Finished Water Supplies." *Arch. Ind. Hyg. and Occupational Med.*, **9**, 488 (1954).
4. Hoak, R. D., "The Causes of Taste and Odors in Drinking Water." *Water and Sewage Works*, **104**, 243 (1957).
5. Palmer, C. M., "Algae and Other Interference Organisms in the Waters of the South Central United States." *Jour. Amer. Water Works Assn.*, **52**, 7, 897 (July 1960).
6. Middleton, F. M., Rosen, A. A., and Burttschell, R. H., "Manual for Recovery and Identification of Organic Chemicals in Water." Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio (May 1959).
7. Hyndshaw, A. Y., Langhlin, H. F., Colebaugh, D. C., and Filicky, J. G., "Factors Influencing the Efficiency of Activated Carbon. *Jour. N. Eng. Water Works Assn.*, **66**, 36 (1952).
8. Middleton, F. M., and Lichtenberg, J. L., "Measurements of Organic Contaminants in the Nation's Rivers." *Ind. and Engr. Chem.*, **52**, 99A (June 1960).
9. Orford, H. E., Raud, M. C., and Gellman, I., "A Single Dilution Technique for B.O.D. Studies." *Sewage and Industrial Wastes*, **25**, 3, 285 (Mar. 1953).
10. "Standard Methods for the Examination of Water and Wastewater." 11th Ed., Amer. Pub. Health Assn. (1960).

NATIONAL ENGINEERS' WEEK

February 18–24, 1962, is National Engineers' Week. The theme is "Economic Growth Through Professional Engineering."

EXPERIENCES IN CLEANING THE HYPERION SLUDGE OUTFALL PIPE

J. A. Frank

Outfall Line Construction

The Hyperion Sewage Treatment Plant is located in El Segundo, California, on the eastern shore of the Bay of Santa Monica and the effluent for both sludge and treated wastewater empties into this large bay.

Extensive research work was done before deciding to use the Bay of Santa Monica, both from the standpoint of technical studies of underwater currents and from such factors as dispersion, dilution, and current direction. The report to the California State Pollution Commission recommended that, where ocean outfalls are used, effluents should be discharged in deep water a long distance from the shore line.

Accordingly, the sludge line was designed to be more than 7 miles long with the discharge approximately 312 ft deep. The treated wastewater outfall was slightly longer than 5 miles and discharged at a depth of 200 ft through diffusers. The entire shore line to the east of both outfalls is dotted with resort towns and it was important that the beaches be protected in both the aesthetic and public health sense.

The sludge line itself was constructed of a 22-in. OD steel pipe, having a wall thickness of $\frac{5}{8}$ in. with a $\frac{1}{2}$-in. cement-mortar lining. The exterior was covered with two layers of fiber glass wrap, each with a spray coat of coal tar enamel. There was a final wrap of paper felt, again with a sprayed coal tar enamel coat. Approximately $2\frac{1}{2}$ in. of aggregate was added to the pipe exterior to produce a negative bouyancy of approximately 40 lb/ft.

This pipe was delivered to the beach and then welded to produce a pulling length of approximately 600 ft. Since the interior cement mortar lining had been cut back 6 in. on each length, a special machine lined the 12-in. space at each weld to produce a smooth continuous bore for the entire 600 ft. working length.

The method of installation was to use the comparatively new pulling technique. A bulkhead and sled were attached to the leading end. Using an offshore winch barge, 600 ft were pulled, the pulling suspended, the next 600 ft rolled into position and an epoxy resin joint piece fastened to the interior of the leading pipe and the following length by means of a plastic adhesive, the joint welded, the exterior wrapped and coated, and then the pulling resumed until the entire outfall had been pulled into its final position.

The heading for the line is close to west, which puts the outfall a maximum distance from the shore line. The line was pressure tested and then the bulkhead was blown off the end of the line.

Coefficient Reduction

After the line was put in service during the summer of 1958, the line was carefully tested to establish the friction coefficient and it was found to be slightly more than 145. Continuous

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This paper was presented at the Spring Meeting of the New York Water Pollution Control Association, Rochester, N. Y., June 12, 1961.

checks revealed that in December 1958, the coefficient had fallen from higher than 145 to approximately 115 and was continuing to drop. Plans were made so that this line could be cleaned in the late summer of 1959.

Line Testing

It was decided to put a "prover" through the lines to make sure that there were no obstructions and to assure clear passage of the cleaner.

The "prover" is a spool-like device so made and dimensioned that if it passes through the pipe, then the chances of the cleaner sticking will be reduced when going through bends, fittings, etc.

Further, the "prover," if it has to squeeze through an obstruction or an out-of-round section, will be marked and it will be known that there is a likelihood of the cleaner itself having trouble going through the section. Finally, it is so made that if it does stick, it is possible to destroy it and have it wash out of the line. This will leave the line open, but the obstruction or difficult section could be located prior to destruction. The prover was to carry the locating devices that would also be used in the cleaner, namely a "knocker" and an oscillator. The reason for using both audio frequency and radio frequency devices was that the radio frequency device will not function under water but the audio frequency device or "knocker" can be located by means of underwater microphones connected to surface amplifiers. The radio transmitter was employed so that the cleaning devices could be located, when floating, by means of a directional antenna.

In September 1959, the preliminary work started. Anchors were placed on the line at half-mile intervals so that with buoys it would be possible to slide the underwater microphone down the anchor lines and the prover could be located in the outfall.

At ranges greater than 2½ miles, it was difficult to triangulate, and underwater television was employed to locate the anchors on the pipe line.

In order to find the buoys rapidly while following the prover, a short mast with a perforated metal box at the top, painted orange, was employed. This made it possible to find it by radar if it was impossible to do so visually.

Cleaner Design

Since it is almost impossible for a diver to work in 312 ft of water, the prover and the cleaner were designed with aluminum pontoons so that when they emerged from the outfall, they would float to the surface. In order to resist the crushing force of the water pressure at this depth, the pontoons were inflated with an air pressure of 135 psi.

At the pump station there were bends and fittings, including Y branches, that the prover and cleaner must negotiate. An actual check revealed that the ID and the radii of these bends and fittings were non-standard and it was necessary to revise the cleaner design and shorten the pontoons.

Cleaning Operation

The prover, equipped with the knocker and the oscillator, was inserted in the pipe. After passing the prover through the fittings into the main outfall, the equipment was put aboard the boat and the recovery crew stood by offshore. The sludge pumps were started by remote control and two-way radio liaison was maintained with shore crews who relayed pressure and quantity readings every 15 min. Since the prover itself did some cleaning during its passage, the pumping head dropped and the quantities increased. The prover was followed through various listening points and because the quantity being pumped was rising, the velocity of the prover was also increasing. At this time the problems of maintaining the boat in position at

each buoy became more difficult and the crew proceeded directly to the outfall terminal.

The heading of the signal obtained on the directional antenna showed the prover to be out of the line and some distance away. This was not credited and the crew continued to wait for the prover to rise to the surface. At nightfall the waiting was given up and the boat returned to shore.

The following day, because it was thought that possibly the prover had emerged and was lodged under debris the underwater television was used in an attempt to learn whether the prover was close to the submerged outfall. Heavy seas precluded this attempt in midafternoon.

Prover Recovery

The next morning, while en route to the outfall, broadcasting on the fisherman's frequency, a reward for finding the prover was offered. At approximately 11:50 that morning a message was received from the shore crew that the prover was at the Venice, California, police station.

It was learned that the prover had emerged from the pipe and floated to the surface at least ½ hr earlier than expected. A favorable wind had taken it ashore and at 11:30 PM a student walking on the beach had discovered it. A group of students dragged it out of the water.

The next morning the knocker was still operating and fearing that there was a bomb attached to this diabolical device, they notified the Venice police. The Venice police notified the Los Angeles police bomb squad who came to the scene and "disarmed" the bomb.

Since the prover was not marked or damaged in any way, it was placed back in use. However, before this, appropriate identification was painted on it.

As the specific gravity of the liquid being pumped through the sludge line is less than that of sea water, careful weighting of the prover and also the cleaner was done in order to insure that they would have only a slight positive buoyancy and to insure that the devices would not wear themselves out on the roof of the pipe during the trip through the line.

The cleaner was made of a forward piston followed by an element carrying split rattan plastic-processed brooms, followed by an element of rubber duck squeegees, followed by a rear piston. There were three pontoons with articulation between each to allow the cleaner to negotiate the bends, Y branches, fittings, etc.

On the day when the actual cleaning was done, after some difficulty in negotiating a Y branch, the same operational procedure was set up on the boat. Again two-way radio liaison was established with the shore to send pressure and quantity measurements every 15 min. Again, the pressures decreased and the quantities increased.

Results

Because of the experiences with the prover it was decided to proceed to a point over the outfall, arriving there ½ hr earlier than the cleaner could arrive even with maximum velocity in the line. The cleaner was soon afloat and it was hoisted aboard and found to be in excellent condition. A friction factor in excess of 135 was measured after the cleaning process.

Acknowledgments

Indebtedness is due the entire staff of The Hyperion Sewage Treatment Plant and many of the staff of the City Engineers office of Los Angeles for the valuable information and complete cooperation in accomplishing this work.

We are also indebted to many of the staff and principals in the Hyperion Engineers.

TURBINE MIXER AERATION IN AN ACTIVATED SLUDGE PLANT

William G. Barker, R. H. Otto, D. Schwarz, and B. C. Tjarksen

This is a report on the performance of a sparged turbine mixer aeration system installed in an activated sludge plant after successful and intensive studies in earlier pilot plant work (1). Sustained plant operation results have demonstrated the ability to handle loadings up to 550 lb of applied BOD/day/1,000 cu ft of aeration tank volume with 75- to 85-per cent BOD reduction. Air requirements have averaged 220 cu ft of air/lb applied BOD. Total power requirements including both mixer and air compressor horsepower have ranged from 0.35 to 0.45 kwhr/lb of BOD removed. Plant performance has fully confirmed the results obtained in the pilot plant.

History

The Abbott Laboratories process wastewaters were previously treated in a conventional activated sludge plant in which the aeration tanks were equipped with hydraulic ejectors for air diffusion. It became apparent that dissolved oxygen would become a limiting factor as the organic load to the treatment plant increased. Reserve aeration capacity of the aeration equipment had not been realized since the hydraulic ejectors tended to foul and could not be kept at peak efficiency without repeated cleanings.

To maintain the wastewater treatment facilities ahead of continuing company growth necessitated finding an improved method of aeration in existing tankage or building additional tanks of conventional design. Intensive pilot plant studies were conducted from June to Dec. 1957 to determine the most effective means of increasing the treatment efficiency and capacity of the existing facilities. Based on the encouraging results obtained through the use of a sparged turbine mixer aeration system in the pilot plant, it was decided to replace the existing plant aeration equipment with sparged turbine mixers.

Design and Installation

Optimum pilot plant performance had been obtained when the mixer input was 0.8 hp/1,000 gal of aeration tank volume with 200 cu ft * of air per pound of BOD applied. Extrapolation to the main plant indicated that 260 hp would be required to maintain the same power input in a basin of 330,000-gal capacity. The combination of impeller speed and diameter was designed to draw 90 per cent of rated full load mixer motor current. This would then allow for continuous operation under varying conditions of liquid viscosity and mixed liquor solids concentration. Therefore, a total of 300 mixer hp was selected to operate at 90-per cent input. This was felt to be conservative since the main plant would operate with a 12½-ft liquid depth whereas the pilot plant operated with an 8-ft liquid

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This paper was presented at the 33rd Annual Meeting of the Water Pollution Control Federation in Philadelphia, Pa., October 2–6, 1960.

* Standard conditions.

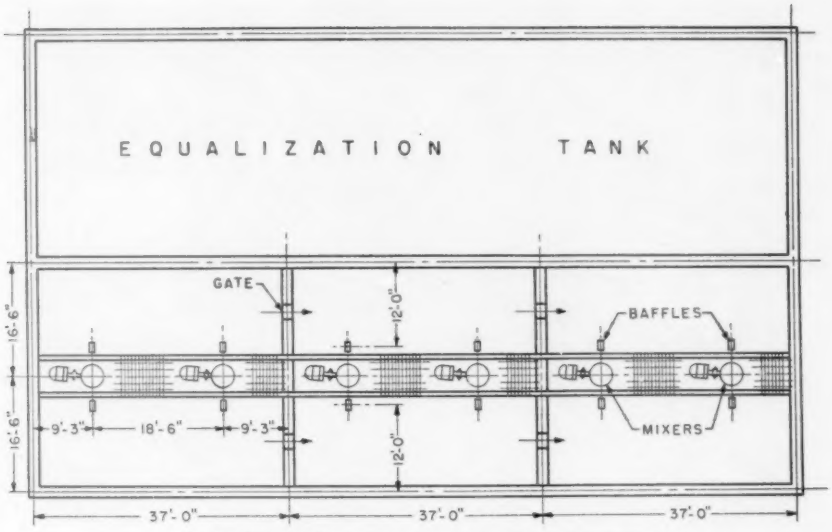

FIGURE 1.—Mixer and compartment arrangement.

depth. An increase in oxygen transfer efficiency was anticipated with the increased depth.

Mixer sizing was reduced to a selection between six 50- and three 100-hp models. Equal oxygen transfer performance was expected from either selection. An economic evaluation of the two sizes indicated that the six 50-hp mixers would provide a slightly

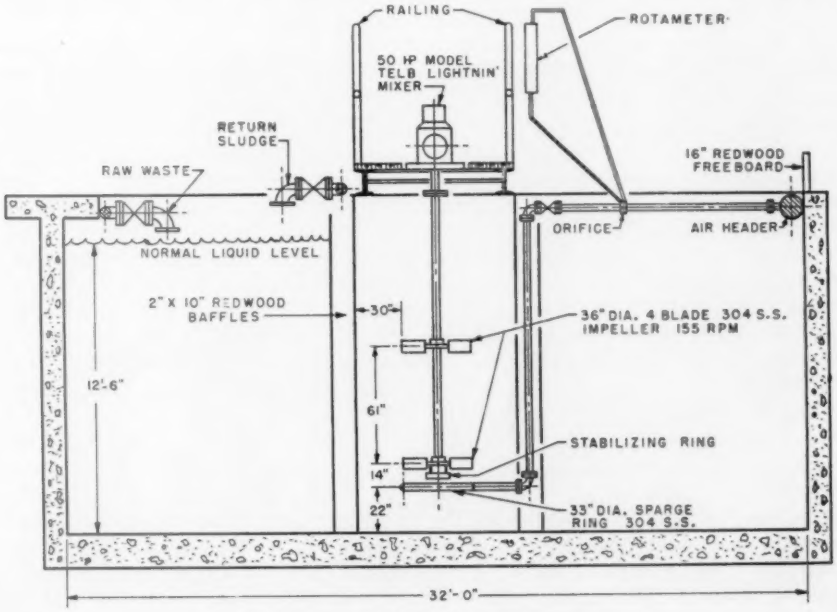

FIGURE 2.—Typical mixer arrangement.

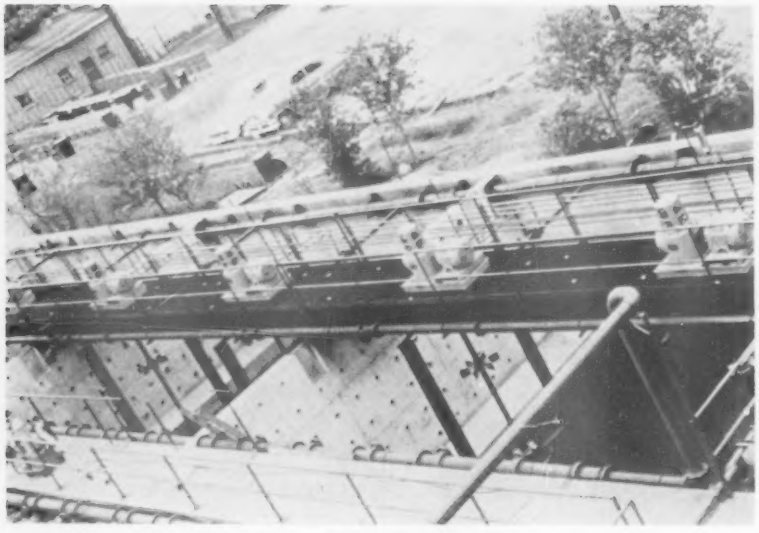

FIGURE 3.—General view.

lower installed cost. However, this size was selected primarily because it was felt that greater flexibility and efficiency of operation would be obtained. Failure of a 100-hp mixer would represent a loss of 33 per cent of oxygen transfer capacity whereas failure of a 50-hp mixer would only represent a capacity loss of 17 per cent. The smaller mixers would also provide more flexible control in periods of excess dissolved oxygen or foaming when it might become advantageous to stop one or more of the mixers.

Six 50-hp turbine mixers were therefore purchased.

Aeration facilities in the main plant consisted of two identical 330,000-gal aeration tanks. Provisions were made in March 1958 to bypass one of the tanks by sending all the raw waste to the remaining aeration tank. The idle tank was then drained and flushed. Construction work began immediately with the removal of the hydraulic ejectors and associated piping. Two concrete compartment walls were poured which divided the aeration tank into three identical compartments each 36 ft long by 32 ft wide with a 12½-ft liquid depth. The compartments were each dimensionally similar to the pilot plant compartment in length and width, but were approximately 50 per cent deeper.

Two 16-in. structural steel beams were installed to serve as supports for the mixers. Each beam spanned the length of the tank with the compartment walls as intermediate supports. Beam spacing was made wide enough to accommodate a full length walkway of steel subway grating. This provided easy access to the two mixers in each compartment. Vertical wood baffles of 2 in. by 10 in. redwood lumber with steel stiffening angles were installed at each mixer to prevent vortexing. The mixer and baffle arrangement is illustrated in Figures 1 and 2.

Sparge rings with diameters of 33 in. were fabricated from 2½-in. stainless steel pipe and installed beneath the lower impeller of each mixer. Each sparge ring had 24 equally spaced ¾-in. top holes and 4 equally spaced ¼-in. bottom weep holes. Previous experience in fermentation operations indi-

cated that sparge ring design would not be critical. Sparge ring diameter was made slightly larger than the impeller diameter to introduce the air in the zone of maximum turbulence. Sparge ring holes were made large enough to eliminate plugging problems.

Piping was designed to permit any of the three aeration compartments to be taken out of service without affecting the operation of the other compartments. Valved lines for raw waste, sludge, air, and drainage were provided for each compartment. Each compartment wall had two slotted channels with aluminum stop gates for mixed liquor flow. It was felt that the separate compartments, multiple mixers, and piping scheme provided the most flexible arrangement and one that would permit the greatest continuity of operation.

Installation proceeded smoothly and, after the coating of all bare metal surfaces, the modified aeration tank was returned to service in early June 1958. The agitator shafts and air piping were painted with an air cured modified epoxy-phenolic paint. Other piping received conventional asphaltic base coatings. The aeration modifications took 12 wk from time of tank draining to startup. Figures 3 and 4 show the completed installation.

Operation

No mechanical difficulties were encountered during the startup operation. However, power checks of the mixer motors revealed that each of the motors was drawing only 60 per cent of rated full load motor current at the desired air flows. Either the speed or impeller diameter could be increased to draw increased power. Speed could be varied through the use of change gears which could be readily installed. The speed increase required would have brought the shaft speed into the critical range which might have necessitated the use of steady bearings. This would not have been desirable since maintenance on the bottom bearings would have required periodic tank draining.

Impellers of 36-in. diam with new stabilizing rings were ordered to re-

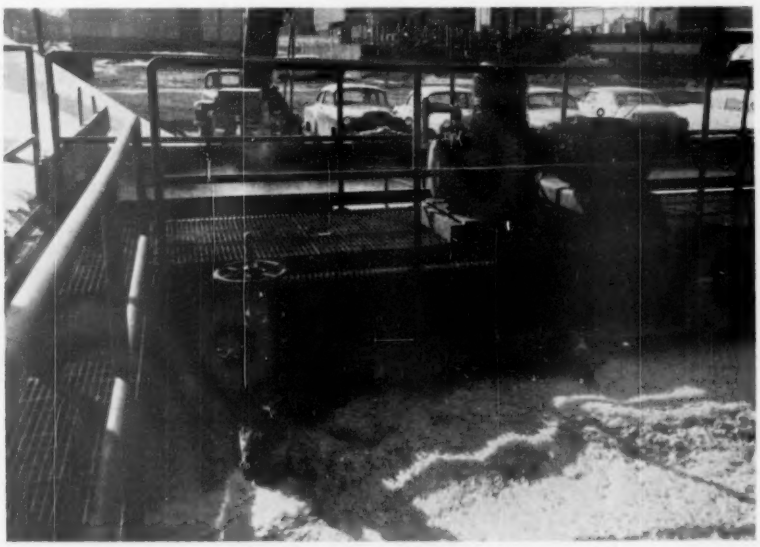

FIGURE 4.—Turbine aerator.

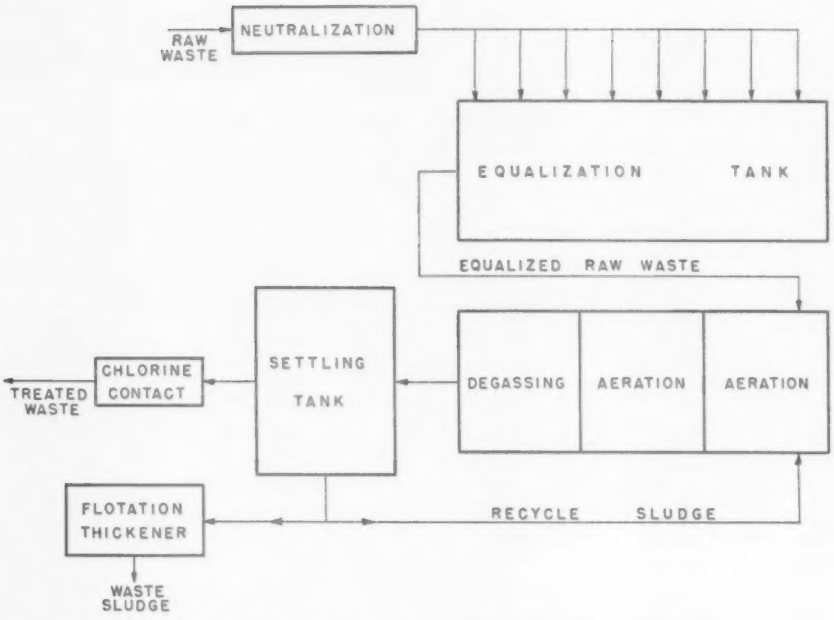

FIGURE 5.—Wastewater treatment plant flow diagram.

place the 30-in. diam impellers originally supplied. The larger impellers were installed during low flow periods by taking one aeration compartment out of service at a time. Baffle supports which had shown signs of weakening were reinforced. The larger impellers operated with the motors drawing 92 per cent of rated full load current.

Air rates to the sparge rings were metered with a bypass rotameter connected across an orifice in each of the sparge ring air supply lines. Since the air distribution piping to each of the six mixers was identical it was only necessary to check air rates at one mixer to determine air rates to the others.

The unmodified aeration tank was used as an equalization tank since only one tank was now required for aeration. Air alone was fed to the hydraulic ejectors for agitation and for possible solvent stripping. Figure 5 is a schematic drawing of the flow pattern currently used in the treatment plant.

No attempt is made to separate primary solids in the present treatment process. Data have shown that most of the BOD in this process wastewater is in the soluble form. Primary solids are collected along with the activated sludge in the secondary settling tanks.

Data and Results

Full power operation began during the second week of August 1958 with the mixer motors running at 92 per cent of rated full load current when driving the dual 4 bladed 36-in. diam impellers at 155 rpm. Compressed air at 500 cfm was supplied to each of the sparge rings.

With all six mixers running it was impossible to obtain satisfactory settling in the secondary sedimentation tanks. The mixed liquor leaving the last aeration compartment was so highly gasified that it had the appear-

ance of the pressurized influent to a flotation unit. In fact, there was a marked tendency for the suspended solids to float. It was apparent that the desired mixed liquor solids concentration of 3,000 to 3,500 mg/l could not be maintained unless corrective action was taken. Clarification studies in the pilot plant had shown that sedimentation would be superior to flotation for this mixed liquor in producing an effluent with low suspended solids content. Attention was therefore centered on improving the operation of the existing settling tanks. The two mixers in the last aeration compartment were then turned off and the air to those two sparge rings was reduced to 300 cfm each. This improved settling action markedly. The desired effect was attributed to a combined degassing and reflocculating phenomenon in the last compartment.

The following became the standard method of operation and the conditions under which all the data were collected. Raw wastewater flow after equalization was subjected to aeration in two compartments with a total of 2,000 cfm of air and degassing in one compartment with a total of 600 cfm of air. In calculating applied loadings the degassing compartment was arbitrarily assumed to have an equivalent value of half an aeration compartment and half the air used for degassing was included in the air requirements for aeration. This was felt to be a conservative approach since the BOD removal occurring in the degassing chamber would probably be poor due to the inefficient method of air introduction.

Standard analytical methods (2) were used for analyses under closely supervised conditions. Influent raw waste samples were composited from an automatic sampler which collected

TABLE I.—Wastewater Treatment Plant Operating Data*

Date	Avg Flow (mgd)	BOD Loading (lb/1,000 cu ft)	BOD Rem. (%)	BOD Loading (lb/lb MLVSS)	Air Used (cu ft/lb BOD applied)	Air Used (cu ft/lb of BOD removed)	Energy Used (kwhr/lb BOD removed)	Sludge Prod. (lb/lb BOD removed)
1958								
Aug. 18	1.04	510	70	3.4	193	276	0.45	0.60
↓ 25	0.87	545	74	3.0	182	245	0.40	0.75
Sept. 1	0.84	580	76	2.5	170	225	0.36	0.60
8	0.73	505	81	1.8	197	244	0.40	0.86
15	0.67	592	80	3.4	168	209	0.34	0.77
22	0.58	505	82	1.8	198	242	0.37	0.60
↓ 29	0.63	470	80	1.8	211	263	0.36	0.82
Oct. 6	0.61	625	85	2.4	160	186	0.28	0.50
13	0.53	432	84	2.0	229	272	0.36	0.64
20	0.57	552	79	2.6	180	227	0.36	0.51
↓ 27	0.56	532	80	2.3	186	230	0.36	0.53
Nov. 3	0.55	445	81	2.0	223	276	0.45	0.63
10	0.58	472	72	2.4	209	290	0.41	0.82
17	0.54	576	83	2.5	172	206	0.32	0.61
↓ 24	0.35	336	83	1.5	294	357	0.47	0.83
Dec. 1	0.45	475	78	2.2	211	269	0.43	0.83
8	0.48	465	50	3.1	214	432	0.57	0.79
15	0.52	496	69	2.4	201	292	0.44	0.69
22	0.29	248	86	1.2	400	460	0.63	0.92
↓ 29	0.28	232	89	1.0	427	476	0.54	0.84
1959								
Jan. 5	0.46	475	80	1.7	209	262	0.36	0.74
↓ 12	0.49	403	84	1.5	246	294	0.43	0.75

* Weighted averages.

TABLE II.—Comparison of Operating Data from Main Plant and Pilot Plant*

Item	Main Plant	Pilot Plant
Run duration (days)	154	31
Applied BOD (lb/1,000 cu ft)	475	453
BOD removed (%)	78.5	78.7
Applied BOD (lb/lb MLVSS)	2.2	3.75
Air used (cu ft/lb BOD applied)	222	215
Air used (cu ft/lb BOD removed)	284	274
Power used (kwhr/lb BOD removed)	0.41	0.36

* Weighted averages.

1,440 samples per day through a solenoid valve and timer arrangement. All other liquid samples were obtained by compositing 24 hourly grab samples.

Table I shows the weighted averages of 22 wk of continuous operation.

BOD removal increased steadily during the first three weeks of operation under full power and entered the 80- to 85-per cent removal range. For the next nine weeks performance remained at this level. One of the mixers had been making unusual sounds since startup. This mixer was shut off and checked carefully for a week, but nothing abnormal could be found. The extended shutdown, however, dropped the BOD removal to 72 per cent.

The next three weeks were normal, but during the week starting Dec. 8, 1958, a waste was received at the treatment plant to which the activated sludge could not acclimate. Dissolved oxygen climbed from the usual trace quantities to abnormally high levels for the BOD loadings applied. Aeration tank temperatures dropped sharply and the treatment plant effluent turned from a sparkling to a hazy liquid containing a greatly increased amount of colloidal material. BOD removal during that week dropped to 50 per cent. The sludge soon began to recover from the initial shock and BOD removal rose to 69 per cent during the week starting Dec. 15, 1958. Dissolved oxygen levels, aeration tank temperature, and effluent quality returned to normal. Performance thereafter was above 80 per cent.

No attempt was made to vary air or mixer power input except on week ends when, because of greatly reduced flow and organic loading, two or three of the mixers could be shut off. Constant air supply to the sparge rings was maintained at all times.

Discussion

Operating results in the main plant have met or exceeded the pilot plant results in all respects. Scale-up was based on dimensional similarity of the aeration compartment, equivalent power input per 1,000 gal of aeration volume, and equal air supply per pound of BOD applied. Table II is a comparison of the main plant results with the pilot plant results for the closest equivalent BOD loading rate, and Table III is a comparison between two operating periods. All the results and observations discussed apply to this particular process waste stream. The application of any of these data to any other waste stream should be investigated in separate studies.

Continuous operation over a 22-wk period has demonstrated the ability of the activated sludge plant to handle loadings of 450 to 550 lb applied BOD

TABLE III.—Comparison of Main Plant Operating Data from Two Separate Six Month Periods*

Item	1958	1960
Run duration (days)	154	168
Applied BOD (lb/1,000 cu ft)	475	336
BOD removed (%)	78.5	84.2
Applied BOD (lb/lb MLVSS)	2.2	1.67
Air used (cu ft/lb BOD applied)	222	302
Air used (cu ft/lb BOD removed)	284	358
Power used (kwhr/lb BOD removed)	0.41	0.50

* Weighted averages.

per day per 1,000 cu ft of aeration tank volume using sparged turbine mixer aeration. This was done using only four of the six mixers installed. At present, the concentration of dissolved oxygen appears to be a limiting factor since only occasional traces are present under high loading conditions. It is likely that BOD removal above 85 per cent will be achieved when the other two mixers can be used. Further reduction of the suspended solids lost with the plant effluent will also contribute to increased BOD removal.

The treatment plant's capacity for handling high BOD loadings has eliminated the necessity for providing additional aeration tankage, associated air compressors, and distributor piping. Expansion using conventional aeration equipment would have necessitated the construction of at least six more aeration tanks. A conventional installation would have been physically impossible on the land area allotted for waste treatment facilities. Not only has premium land space been conserved, but one of the former aeration tanks has been released for other uses. Appreciable benefit has been realized from the use of this tank as an equalization basin with the accompanying reduction of hydraulic and organic load variations and cost of neutralization chemicals. The installed cost of the sparged mixers is well below the cost that would have been required to purchase additional tankage and compressors. Installation time of course was also decreased.

Economy of operation is another factor which has been demonstrated. Aeration power requirements of 0.35 to 0.45 kwhr/lb BOD removed are well below those of the hydraulic ejectors formerly employed which consumed 0.56 kwhr and are below the aeration power requirements of many conventional domestic sewage activated sludge plants. Since no attempt was made to vary the power input with decreased applied BOD loadings, the lower BOD loadings show the highest power requirements. It is anticipated that power requirements can be reduced through finer control of the dissolved oxygen levels.

The non-fouling characteristics of the sparged turbine system are evident from an examination of the plant operating data. Performance remained at a constant level for 22 wk. There is little that can happen mechanically that would reduce oxygen transfer efficiencies with the exception of erosion of the impeller blades. Periodic inspections of the impellers reveal no visible erosion of the blades. The blade tips still appear sharp-edged. Power checks confirm that the mixer motors are continuing to draw 90 per cent of their rated full load motor current. No fouling or plugging problems have occurred with the sparge rings. There has been no accumulation of solids in the bottom of the aeration tank compartments.

There has been no indication that mixer maintenance costs will be excessive. Two bearings were replaced in one mixer after 15 months. This work was easily done in place. None of the other mixers has required maintenance other than routine lubrication. The modified epoxy-phenolic coating applied to the steel mixer shafts failed after 6 months and was not replaced. Corrosion and erosion on the shafts appear negligible.

Foaming at first presented no problem except on week ends when both the flow and organic loading would drop off sharply with corresponding increase in the dissolved oxygen level. Control was effected by stopping all but one mixer while maintaining sparge ring air on the others. This was enough aeration to maintain an adequate dissolved oxygen level.

Some change occurred in the characteristics of the wastewater which caused foaming to become more pronounced during week day operation. Antifoam agents proved unreliable and

TABLE IV.—Variation of Oxygen Transfer Efficiency with Distance From Mixer

Run No.	Temp. (° F)	DO Conc. (mg/l)	Oxygen Transfer Efficiencies at Various Distances from Mixer (%)				
			5 ft	7 ft	9 ft	11 ft	13 ft
1	98	0	15.3	12.5	21.5	>25.8	>25.8
2	98	0	7.7	11.7	17.2	23.7	>25.8
3	99	0	12.0	15.0	16.3	18.9	17.9
4	97	0	13.4	16.3	>25.8	>25.8	>25.8
5	97	0	13.4	19.6	>25.8	>25.8	>25.8
6	95	0	5.5	10.3	21.0	24.0	>25.8
7	91	0	—	10.5	10.0	6.5	10.5
8	95	0	21.8	>25.8	>25.8	>25.8	>25.8
9	96	0	14.6	21.0	>25.8	>25.8	>25.8
10	92	0	7.4	12.4	17.9	17.0	18.7
11	92	0	13.9	>25.8	>25.8	>25.8	>25.8
12	99	0	18.0	>25.8	>25.8	>25.8	>25.8
13	97	0	15.3	>25.8	>25.8	>25.8	>25.8
14	97	0	25.8	>25.8	>25.8	>25.8	>25.8

expensive. Water sprays would have increased the hydraulic loading. Recirculation of effluent to foam spray nozzles would have presented plugging problems. Control of foam was achieved by extending the tank freeboard 16 in. with redwood lumber and allowing the foam to flow from the aeration compartments across the concrete dividing wall to the adjacent equalization tank. The foam would break with time and the air agitation employed in the equalization tank and be recycled back to the aeration tank with the raw waste feed.

An oxygen analyzer was used to measure the oxygen concentration of the off gas from the main plant aeration compartment. The gas collector was an inverted 55-gal drum which could be moved along an overhead rail support fastened between the mixer platform in the center of the tank and the outer wall of the tank. Oxygen transfer efficiencies were determined at 2-ft intervals. Table IV shows the actual oxygen transfer efficiencies obtained at varying distances from the mixer in 14 separate traverses of one aeration compartment. Each of these traverses was made on a different day.

The oxygen analyzer could measure transfer efficiencies up to 25.8 per cent. In general transfer efficiencies exceeded 25.8 per cent at points further than 7 ft from the mixer. Average transfer efficiencies were calculated to be over 20 per cent. In calculating an average transfer efficiency for the compartment it was assumed that the sparge ring air was distributed in inverse proportion to the transfer efficiencies measured. It was also assumed that the transfer efficiency remained the same at any point of a two-foot wide annular ring of varying diameter with the mixer as the center. Transfer efficiencies in the pilot plant were as high as 17 per cent. The difference in transfer efficiency of the two plants is attributed to the 50 per cent greater liquid depth of the main plant.

The major problem associated with the use of the sparged mixer has been the excessive gasification of the mixed liquor with subsequent settling difficulties in the secondary sedimentation tanks. Degassing was obtained by idling two mixers and using sparge ring air to provide gentle agitation. Studies were conducted in the pilot plant on sparge ring versus drilled pipe headers for degassing. The drilled pipes were more effective.

Immersible ultrasonic transducers were tried in the main plant for de-

gassing. After running the ultrasonic equipment for one month this study was dropped because the apparent equipment requirement would have made this method prohibitive in cost. Other degassing methods which proved ineffective included low power mixer agitation without air and baffling of the connecting channel between the aeration and settling tanks.

Observations in the pilot and main plants led to a redesign of the existing settling tanks which now enables them to clarify and remove both settling and floating sludges simultaneously. It is expected that the degree of degassing required will be materially reduced.

Continuing Studies

Aeration studies are being continued to discover the effect of specific wastes on aeration efficiency. Clarification studies are continuing primarily with respect to the performance of the modified settling tanks. Sludge disposal studies are also in process.

Acknowledgment

The waste disposal program has been most capably initiated and coordinated by the Abbott Waste Disposal Committee comprising executives from the Production, Development, Utilities, Engineering, and Research Departments. Sincere appreciation is expressed to the Committee members; to L. S. Kraus, Manager of the Greater Peoria Sanitary District, Peoria, Illinois, and consultant to Abbott Laboratories; to the Mixing Equipment Company of Rochester, New York; and to the Abbott personnel who have worked so enthusiastically on the project.

References

1. Barker, W. G., Otto, R. H., Schwarz, D., and Shipton, G. F., "Pharmaceutical Waste Disposal Studies. I. Turbine Mixer Aeration In An Activated Sludge Pilot Plant." *Proc. 13th Ind. Waste Conf.*, Purdue Univ., Ext. Ser. **96**, 1 (1959).
2. "Standard Methods For the Examination of Water, Sewage, and Industrial Wastes." 10th Ed., Amer. Pub. Health Assn., New York (1955).

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SAMPLING DEVICES USED IN THE ANAEROBIC CONTACT PROCESS

Edwin B. Fall, Jr., and L. S. Kraus

Automatic Liquid Sampler

The samplers described in this article were the ones used in a full-scale test operation of the anaerobic process (1). Automatic samplers used should have the following characteristics:

1. The collected sample should be refrigerated at about 40°F.
2. The collected sample should be proportional to the rate of flow.
3. The pump that supplies the sample and the container into which it discharges should be flushed for a sufficient time to assure a representative sample.
4. The cup or device by which the sample is collected should have a large opening which allows the sample taken to discharge rapidly and completely into the sample bottle.
5. The container from which the sample is collected should be drained below the top of the sample cup before the cup discharges into the sample bottle in order to minimize the tendency to collect excessive amounts of floating material.
6. The materials of construction should be corrosion resistant and should not have an inhibiting effect on biological activity.
7. Controls should be provided to collect the desired quantity of sample over the period of sampling.
8. The cost of the sampler should be low.

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This paper was given as a supplement to the paper "Anaerobic Contact Process" presented at the 33rd Annual Meeting of the Water Pollution Control Federation in Philadelphia, Pa., Oct. 2–6, 1960.

Sampler Construction

Figure 1 is a detail of the sampler. The refrigerator which holds a 2-gallon polyethylene bottle is a Little Giant Electric Refrigerator, manufactured by Foremost Commodities Manufacturing Co., 1472 Broadway, New York 36, N. Y.

The pump is an Enpo Submersible Pump, type AU open impeller, available from the Piqua Machine and Manufacturing Co., Piqua, Ohio. It discharges into the stainless steel (16 gage) container at inlet A (1¼-in. stainless steel tubing). It fills container section B and raises float C which closes the one inch stainless steel ball valve D. The flow continues across the bottom of the container at a level below the top of sampling cup E into chamber F from which it is discharged through normally open solenoid valve G to the drain.

The sample flow is continued for about one minute under the control of a time switch. After the flushing time has expired, the time switch closes the solenoid valve. The container fills rapidly filling the sample cup and activating float switch H which de-energizes the sample pump and the solenoid valve and causes the container to drain rapidly through the pump.

When the level in compartment B is sufficiently low, ball valve D opens and the sample is discharged into the refrigerated bottle.

The cycle is thus completed and the pump is ready to start on an impulse from the primary activating control. This may be a switch on a venturi meter, a pressure switch on a pump, a liquid-level switch over a weir, or a time switch.

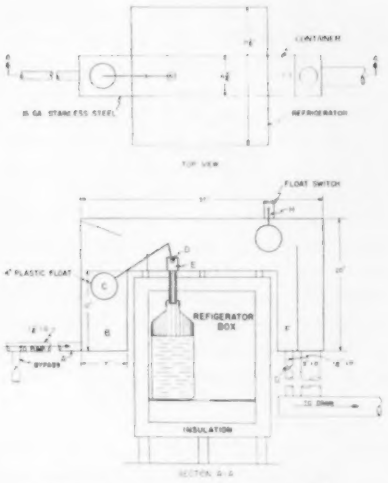


FIGURE 1.—Automatic sampler.

Electrical Controls

Figure 2 indicates the electrical circuit for this sampler. Contact P is the primary activating control which energizes relay R, which in turn activates step relay S. Step relay S, after a proper number of operations have been made depending on the size of the sample desired, energizes relay R_2 and the reset coil S_r of the step relay. Contactor R_2 closes relay R_3 through normally closed float switch F closing two contactors R_3 one of which is a holding contact for relay R_3 and the other starts pump motor M and timer T. Normally open contact T is adjusted to close after a sufficient flushing time has elapsed, thus closing solenoid valve V.

The liquid level in the container rises rapidly opening float switch F which de-energizes relay R_3 which in turn de-energizes the pump motor and the timer. The cycle is thus complete.

Problems of Sampler Operation

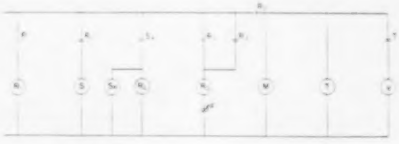
The sampler is essentially an electrically-controlled device. It is obvious that these devices must be of good quality. The total cost, including labor, is about $500. However, an extra investment in relays and switches is well warranted.

The greatest difficulty encountered in operation was the sampling of raw sewage. The pump was occasionally plugged with rags and sometimes the ball valve was not allowed to close by a solid particle deposited on the seat. The only problems that interfered with the sampler operation on effluents were electrical in nature.

Extinction Meter

The extinction meter consists of a photoelectric cell in a water-tight compartment with a glass window on one side of the container. There is a light bulb one-half inch away from the window and positioned so that the beam of light is focused on the photoelectric cell. The light and the water-tight compartment are fastened together and suspended from a four-conductor wire, with two of the wires connected to the photoelectric cell and two connected to the light. The wire is on a pulley so that the light and photoelectric cell can be slowly lowered into the tank. The other end of the wires are connected to a micro-ammeter from the photoelectric cell and from the light to batteries.

The light is lowered into the tank and when it enters the sludge layer the sludge between the light and the photoelectric cell cuts off the light beam and the reading on the micro-ammeter drops to zero. There is a counter that



P — ACTIVATING CONTACT.
R — SINGLE POLE RELAY.
R_2 — SINGLE POLE RELAY.
R_3 — DOUBLE POLE RELAY.
S — ELECTRICAL RESET STEPPING RELAY (MULTIPLE POINT).
T — TIMING RELAY, ADJUSTABLE TO ABOUT 5 MINUTES.
V — VALVE SALENOID.
M — PUMP MOTOR.

FIGURE 2.—Wiring diagram of automatic sampler.

measures the length of wire that has been lowered into the tank and from this and the water depth of the tank the sludge level can be obtained.

The meter works very well and can be used in primary and final settling tanks to determine the sludge level and thereby the pumping rate needed to remove the sludge from these tanks.

Sludge Sampler

The sludge in the anaerobic contact tank was thick and hard to sample, but after trying several different ways a sampling pole was constructed in the following manner. A half inch aluminum conduit with a quarter inch steel rod in the inside is used. A spring clip holder for a four ounce, wide-mouth bottle is centered under the bottom end of the conduit. A rubber stopper is fastened to the quarter inch rod and fits in the bottle. When taking a sample the stopper is put into the neck of the bottle and the pole is lowered to the proper level in the tank. The stopper is then removed from the bottle by pulling on the rod. The concentrated sludge is forced into the bottle by slowly moving the pole up and down about two inches each time. After the sample is collected the stopper is pushed back into the bottle by use of the rod and the pole is removed from the tank.

Reference

1. Fall, E. B., Jr., and Kraus, L. S., "The Anaerobic Contact Process in Practice." THIS JOURNAL, **33**, 10, 1038 (Oct. 1961).

RESEARCH GRANTS

The Research and Training Grants Branch of the Division of Water Supply and Pollution Control reports that 142 Public Health Service research grants totaling $2,116,804 were awarded in the field of water supply and pollution control during fiscal year 1961. These grants were made to institutions in 37 states and the District of Columbia.

Of the year's total, $761,793 was allocated to support 47 new research grants. The remaining $1,355,011 was for continued support of previously approved research grants.

For a complete list of research grants awarded in the field of water supply and pollution control during fiscal 1961 write to:

Chief, Research and Training Grants Branch
Division of Water Supply and Pollution Control
Public Health Service
Washington 25, D. C.

TIPS AND QUIPS

A Beginning

The Five-Minute Car Wash in San Bernardino, Calif., has installed a filtering system to reuse its wash water.

The system reduces the water use by 70 per cent, with the use of this one establishment dropping from 15,000 to 4,600 gpd. The city officials are pleased and are looking forward to a far wider use in many industries such as laundries, dairies, and food processing plants. Not only is this a welcome change from the usual increasing per capita use but the owner is very happy since his average water bill has dropped from $96 to $28.

New Idea for Odor Control *

The City of Lake Worth, Fla., was plagued by odors at lift stations and decided to take positive action. After instituting a thorough program of housekeeping, lift-station odors were reduced by 90 to 95 per cent. By accident it was discovered that vanilla extract effectively masked the residual odors. Now, according to Joe C. Woolf, Superintendent, they use a spray of vanilla extract (35 per cent alcohol) diluted 1 to 20 with water and have a candy kitchen instead of a lift station.

Safety Award

The Fort Wayne News Sentinel, July 25, 1961, contained the following news item:

A certificate of meritorious achievement was presented to the employees of sewage treatment plant today for completing over 600,000 man hours of work without time loss due to injury.

Under the supervision of Paul Brunner, the plant workers have gone 2,793 consecutive work days without an impairing injury. Presenting the award was Ed Hall, engineering representative of the Standard Accident Insurance Company, in the office of Mayor Paul M. Burns.

The Building, Engineering, Light Service, Meter Test, and Sub-Station Departments have not attained certificate records but are approaching the mark and will receive a letter of commendation from Mayor Burns.

Force-Account Construction

Walter L. Picton, Director, Water and Sewage Industry and Utilities Division, Business and Defense Services Administration, Department of Commerce, reports that a study of utility construction for the years 1952 through 1959 reveals interesting data concerning utility expansions.

More than 13 per cent of the construction of public water utilities and 5 per cent of public sewerage utilities was done by force account.

The fact that the value of sewerage force-account construction in 1959 was $42 million, almost double the 1952 amount, should prove to be of interest to management, consulting engineers, and suppliers.

Federal Agencies Approve Plan to Integrate Radiation Emergency Assistance

Eleven federal agencies have approved an interagency radiological assistance plan to provide advice and assistance upon request from organiza-

* From *California Water Pollution Control Association Newsletter*, Vol. 12 (Aug. 1961).

tions or individuals, in connection with incidents resulting in the loss of control of radioactive materials which involve a hazard or possible hazard to life, health or property.

Presently operating radiological assistance resources of the federal agencies, including the Atomic Energy Commission and Department of Defense emergency radiological assistance teams, are not intended to be replaced or changed by the interagency plan. The plan, however, considerably broadens the base of available emergency assistance through the participation of several federal agencies. As a practical matter, a request to any participating agency will bring into action appropriate aid from the nearest source.

The Interagency Committee on Radiological Assistance, which has been responsible since its formation in May 1958, for the development of the plan, will continue to function. This committee is made up of officials designated to represent the participating federal agencies. The committee is responsible for obtaining federal agency approval on policy matters, for interpretation, for making such changes in the plan as may be desirable in the future, and for assuring the participating agencies that the plan is carried out in a manner consistent with federal statutes and executive orders related to radiological assistance. The plan provides that AEC will periodically inform the participating agencies on progress and development in the administration and execution of the objectives of the plan.

Under the new plan federal agencies will coordinate their radiological assistance health and safety activities with those of state and local health, police, fire, civil defense, and other interested agencies. The plan also calls for setting up a system for the exchange of information among the national and local groups.

The plan proposes the encouragement of the development of local capability to cope with radiological incidents and the development of basic instructional material in radiation protection that will be made available for public safety and public health personnel.

Further information about the interagency radiological assistance plan may be obtained by writing the Director, Office of Operational Safety, U. S. Atomic Energy Commission, Washington 25, D. C.

Skeeter Control

Philadelphia has acquired a fleet of 3-wheeled utility vehicles (see photo) to check parking meter violations and spearhead a drive on mosquitoes. Three of these vehicles, each with only a driver, will be used by the City Health Department and will replace the normal trucks and two-man crews. The savings in wages is expected to save the taxpayers money.

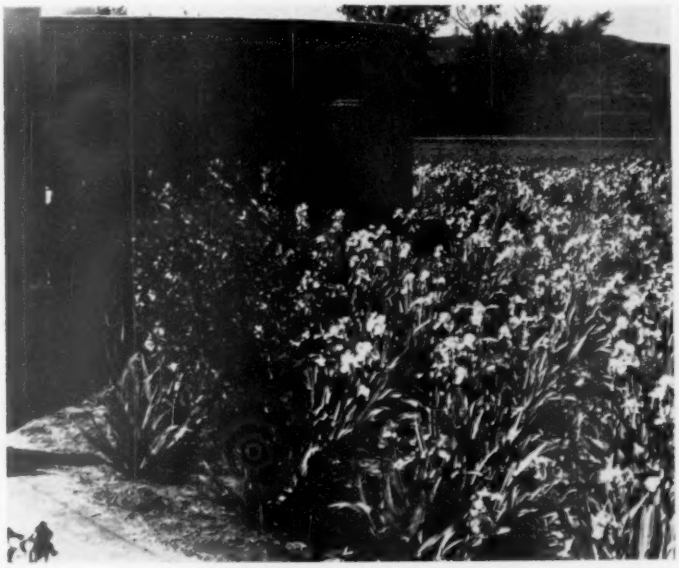
Treatment Plant Beautification

Austin Morgan of College Place, Washington, operates the wastewater treatment plant for that city and serves as Justice of the Peace. He is a certified operator, registered with the Pacific Northwest Pollution Control Association under their voluntary certification plan.

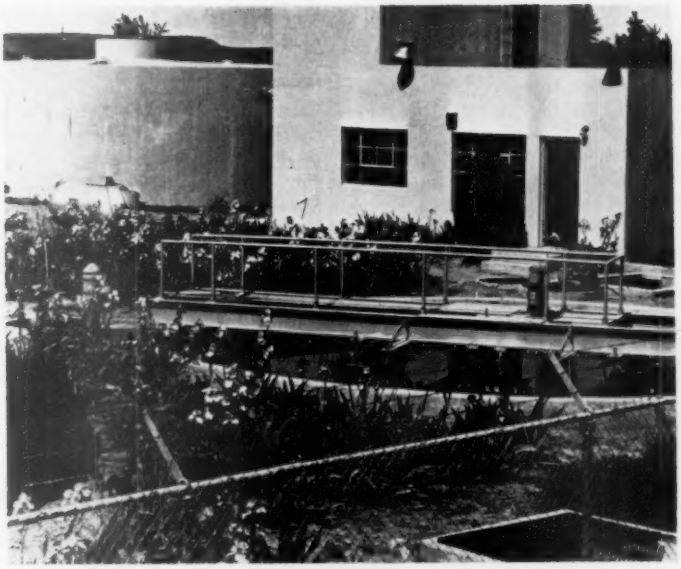
The plant, operated by Mr. Morgan, is unusual as he has landscaped it

with iris. The two photographs show the area near the clarifier and the field by the digester.

He is to be congratulated for his success in softening the usual plainness of such installations.



Iris around the clarifier.



Iris around the digester.

THANK YOU, MILWAUKEE!

An Editorial

At each annual meeting of the Federation, the details of all facets of Federation operation come under close scrutiny of the Board of Control and the membership attending. The meeting itself is the culmination of many hours of work on the part of the Federation officers, committees, and staff.

The exhausting preparations reach their climax just before the meeting so all concerned are alert to any signs of response by numbers or by word. By the second day of the technical sessions there is a strong indication of the final result, but not until the final day are the real results available. The record registration of 2056 will be analyzed in the December Journal.

Whatever the many causes may be, one result is readily apparent—that the water pollution control activities as exemplified by the operation of the Water Pollution Control Federation is making significant strides ahead.

Many expressions of approbation and congratulation have been heard since the meeting. We hasten to pass on a sampling of these comments to those actually responsible for the successful conduct of the meeting. Among the descriptive terms heard were "a bell ringer!" "an outstanding meeting!" "terrific job!" "smoothest meeting ever!" "clockwork precision!"

Where does the credit for a successful meeting belong? Of course, the Federation officers and staff expect and are expected to do all possible for the smooth planning and operation of such a meeting. Beyond this the products of two major committees deserve the highest credit for the meeting's success. The Publications and Program Committee which was under the chairmanship of Dr. George E. Symons produced a technical program with the cooperation of authors and presiders that remains the main core of attraction. This Committee, which starts its planning a full 12 months in advance, pursues an orderly routine to produce technical presentation of a breadth suitable for the varied Federation membership and a depth appropriate for meeting presentation and likely Journal publication.

The second committee deserving of similar notice is the Local Arrangements Committee which this year was under the chairmanship of William N. Konrad of Milwaukee. Even though this Committee does not have the advantage of year-to-year continuity in leadership or membership, this year's Chairman organized a smooth-running team that presented Milwaukee's best to meeting delegates and also made an excellent presentation of the Federation to Milwaukee.

There was strong evidence of public interest in water pollution control. This was measured by the extensive local and national publicity received regarding the significance of events and statements of participants and officers. Here again, appreciation is due the extensive support of the news corps made up from those in Milwaukee, as well as representatives from several member organizations and the Federation Public Relations Committee.

Still another measure of the size and importance of an annual meeting is that afforded by the activity of manufacturers at the meeting. One measure of the sparkle added to a meeting is the fact that over 100 exhibition booths were used by members of the Water and Sewage Works Manufacturers Association, which handles all details of commercial exhibits for the Federation. This figure is of particular significance when compared with 47 booths used a decade earlier when the Federation last met with the Central States Sewage and Industrial Wastes Association as host. With an attendance of 718 that year, the annual meeting nearly tripled its attendance and more than doubled commercial exhibit space in the last decade.

The Federation's appreciation to all concerned is summarized by the expression, "Thank you, Milwaukee!"

R. E. F.

PUBLIC INFORMATION MATERIALS

This list was compiled by the Public Relations Committee of the Water Pollution Control Federation. Knowing that there are other worthwhile items not included, the Federation invites anyone to draw attention to missing items for consideration as additions to the list. Please send at least one copy of each item to the Federation office, 4435 Wisconsin Avenue, Washington 16, D. C.

PUBLICATIONS

Title	Source	Availability
Thoughts Plus Actions Equal Results *The Water Pollution Image* *Where Industry Stands in Water Pollution Control* *Where Research Stands in Water Pollution Control* *Planning the Dedication of the Mill Creek Sewage Works* *Public Relations Aspect of Promoting a Bond Issue* *The Position of States in Water Pollution Control* *Field Trip to the Treatment Works of a New Refinery* *What the Operator Can Do to Promote Better Public Relations* *Market Facts*	Water Pollution Control Federation, 4435 Wisconsin Avenue, Washington 16, D.C.	Limited quantity at no cost
Our Growing Water Problems	National Wildlife Federation, 1412 16th Street, N.W., Washington 6, D. C.	Single copy 25c Quantity rates available
The Water and Sewage Industry Today and Tomorrow	The Water and Sewage Works Manufacturers Association, Inc., 165 Broadway, New York 6, N. Y.	Limited quantity at no cost

Title	Source	Availability
The Living Waters (1961 ed.)	Dept. of Health, Education and Welfare, Public Health Service, Div. of Water Supply and Pollution Control Washington 25, D. C.	25c each
New Resources to Meet Community Sewage Treatment Needs Under the Construction Grants Program		No cost
Statistical Summary of Sewage Works in the United States		15c each
Municipal Sewage Treatment Needs		15c each
Your Career in Sanitary Engineering		25c each
Clean Water—A Challenge to the Nation		No cost
Building for Clean Waters—Construction Grants 5-Year Report		No cost
Federal Water Pollution Control Act As Amended, 1961		No cost
Recreation and Clean Water		No cost
Nature's Wondrous Way with Waste (The Reader's Digest article)		No cost
A Single Answer to Two Sewage Treatment Problems (Water and Sewage Works article)		No cost
How Routine Work of Utility Men Can Make the News (Feb. 61 issue of Public Works)	Public Works Publications, 200 South Broad Street, Ridgewood, N. J.	50c each
Stream Life and the Pollution Environment		Limited quantity at no cost

TITLE	SOURCE	AVAILABILITY
Washing Our Water: Your Job and Mine	Public Affairs Pamphlets, 22 East 38th Street, New York 16, N. Y.	Single copy 25c Quantity rates available
Sewers and Civilization *Sewage Treatment Works* *Vote "Yes" for Sewers* *Financing Water and Sewage Works* *Untreated Sewage—A Community Menace* *Public Bond Issue Campaigns packet*	Portland Cement Association, 33 W. Grand Avenue, Chicago 10, Ill.	Available in the United States and Canada only, at no cost
The Wrong Enemy (Outdoor America Article)	The Izaak Walton League of America, 1326 Waukegan Rd., Glenview, Ill.	Limited quantity at no cost
Idea Packet	Clay Products Association P. O. Box 172 Barrington, Ill.	Limited quantity at no cost
A Water Use Policy *Pollution Abatement in the Pacific Northwest*	Outdoor Writers Association of America, Inc., 10 E. Fayette St., Balto. 2, Md.	Limited quantity at no cost
Everyone Can't Live Upstream *Clean Water and How to Get It*	General Electric Company 1 River Road Schenectady 5, N. Y.	$100.00/100 30c each
On the Water Front	League of Women Voters of the United States, 1026 17th St., N. W. Washington 6, D. C.	25c each
Know Your River Basin		25c each
The National Voter (Apr. and June 1959, Jan. 1961 issues)		10c each
Man and the River		50c each
Little Drops of Water		5c each
The Great River of the West		50c each
Wisconsin Profile—A Summary of Water Use and Administration		
Colorado's Water Resources		50c each

Title	Source	Availability
How to Get Sewage Treatment Works in Ohio	Ohio River Valley Water Sanitation Commission, 414 Walnut Street, Cincinnati '2, Ohio	Limited quantity at no cost
Dickey Data	Water Pollution Control Federation, 4435 Wisconsin Avenue, Washington 16, D.C.	Limited quantity at no cost
Water and Pollution The Crisis	National Water Institute, Rm. 1250, 420 Lexington Ave., New York 17, N. Y.	Limited quantity at no cost
If You Want Air Time	National Association of Broadcasters, 1771 N St., N.W., Washington 6, D.C.	NAB member radio or television station
Search and Research	National Council for Stream Improvement, Inc. 271 Madison Avenue, New York 16, N. Y.	Limited quantity at no cost
Your Clean Streams Program (Pennsylvania Report) *Clean Streams* (brochure-films-exhibits-speakers-literature) *Clean Streams* (newsletter)	Pennsylvania Department of Health, P.O. Box 90, Harrisburg, Pa.	Limited quantity at no cost
Water (pamphlet) *Oyster Development and Survival* (brochure and film)	Northwest Pulp & Paper Association, Tacoma Building, Tacoma, Wash.	Limited quantity at no cost
What Water Means to Ohio	Ohio Water Commission, 1562 West First Avenue, Columbus 12, Ohio	No cost
Pollution Control	Mississippi Valley Association, 1978 Railway Exchange Bldg., St. Louis, Mo.	No cost

Title	Source	Availability
Clean Waters 16mm, sound, color, 20 min	General Electric Company 1 River Road Schenectady 5, N. Y.	Free loan
Engineering Your Health 16mm, sound, color, 13.5 min (San. engr. as a career)	U. S. Public Health Service, Public Inquiries, Washington 25, D. C.	Free loan
Good Riddance 16mm, sound, color, 30 min (crusade for clean streams)	Ohio River Valley Water Sanitation Commission, 414 Walnut Street, Cincinnati 2, Ohio	Free loan
Oil on the River 16mm, sound, color		Free loan
Bear Grass Creek 16mm, sound, color		Free loan
Headline for Harper 16mm, sound, color, 30 min (public works progress)	International Harvester Co. 180 North Michigan Ave., Chicago, Ill.	Free loan
How Our Town Saved the River 16mm, sound, color, 30 min	Portland Cement Association, 33 West Grand Ave., Chicago, Ill.	Free loan
Municipal Sewage Treatment Process 16mm, sound, 13 min	U. S. Public Health Service, Communicable Disease Center, Atlanta, Ga.	Free loan
Our Beautiful Potomac 16mm, sound, color, 15 min	Interstate Commission on the Potomac River Basin, 202 Transportation Bldg., Washington 6, D. C.	Free loan
Progress Report 16mm, sound, color, 15 min		Free loan
The Waters of Coweeta 16mm, sound		Free loan

Title	Source	Availability
Pure and Simple 16mm, sound, color, 19 min (equip. used in ind. waste problems)	Public Relations Dept., Link-Belt Co., Prudential Plaza, Chicago 1, Ill.	Free loan
Refuse Disposal by Sanitary Landfill 16mm, sound, color, 13 min	Communicable Disease Center, U. S. Public Health Service, Atlanta, Ga.	Free loan
Sewers—Guardian of Community Health 16mm, sound, color, 20 min	Clay Products Association, 100 N. LaSalle Street, Chicago 2, Ill.	Free loan
Tale of the Twin Cities	Kerwin L. Mick, Supt., Minneapolis—St. Paul Sanitary District, Box 3598, St. Paul 1, Minn.	Free loan
Waters of the Commonwealth (how anti-pollution program is carried out)	Public Relations, Pennsylvania Sanitary Water Board, P.O. Box 90, Harrisburg, Pa.	Free loan
Pennies for Health Sound, black and white, 13½ min (on water pollution & control)	National Water Institute, Rm. 1250, 420 Lexington Ave., New York 17, N. Y.	Free loan
Investment With a Future 16mm, sound, color, 20 min (history and progress of local pollution control program)	Washington Suburban Sanitary Commission, 4017 Hamilton St., Hyattsville, Md.	Free loan
Water 16mm, sound, color, 14 min	Center for Mass Communication of Columbia University Press, 1125 Amsterdam Ave., New York 25, N. Y.	Purchase or rent

AUTHOR'S GUIDE FOR THE JOURNAL OF THE WATER POLLUTION CONTROL FEDERATION

Source

Material for publication may originate (*a*) in presentation of a paper or discussion at a Member Association Meeting, the Annual Federation Meeting, or any meeting having Federation sponsorship of certain papers; or (*b*) from direct manuscript submission. Those originating from sources (*a*) are publication property of the Journal of the Water Pollution Control Federation, and they are not to be used in other publications without a release from the Editor beyond that included in news reporting of a meeting. At Member Association meetings, manuscripts should be submitted to the Association Secretary who in turn will forward them to the Editor. At Federation meetings, papers may be submitted to a member of the editorial staff directly or through the presider of the session at which the paper was given. Any paper given at a meeting should be so identified.

Manuscripts submitted directly to the Federation office for publication review should be accompanied by a statement indicating whether the manuscript is under consideration for publication elsewhere.

Manuscript Form

Typewritten or duplicated manuscripts on $8\frac{1}{2}'' \times 11''$ paper are preferred. Manuscripts must be double- or triple-spaced using only one side of the paper. The author's name, address, business affiliation and title must be clearly indicated. Text material should be divided appropriately by headings and sub-headings.

Subject Matter

Each paper should include (*a*) a clear, concise introductory statement of the purpose of the paper, (*b*) a logical, connected presentation of the subject matter, and (*c*) a statement of the author's conclusions. Research papers should include a description of methods employed and a discussion of theoretical and practical concepts involved. Data should be presented concisely and to the extent relevant to the paper.

A summary or abstract of 200 words or less should be submitted with the paper. The suggested title for the paper should not exceed 10 words and should indicate the substance of the paper.

Illustrative Material

Photographs, line drawings, and graphs add much to reader interest and value of a paper. Photographs should be glossy, black and white. Line drawings and graphs may be in a similar form or originals with black lines on light paper or linen. Lettering and other details must be large enough to remain legible after reduction to fit printing requirements. Captions should be furnished for all figures and tables.

All manuscripts are submitted with the understanding that editorial alterations of titles, substance, and illustrative material may be necessary.

JOURNAL PUBLICATION PROCEDURES

The Journal of the Water Pollution Control Federation depends heavily on the programs of its Member Association meetings as sources of technical material.

To assist the JOURNAL to maintain a high degree of uniformity and quality of editorial material, certain rules have been established governing publication procedures.

These rules, as prepared by the Federation's Publications Committee and approved by the Board of Control in October 1941, are reproduced herewith:

1. All papers presented before the meetings of the Federation or before any of its Member Associations become the property of the Federation, and publication of these in any but the Federation publications can be made only with specific permission from the Publications Committee.

2. Papers shall be submitted to the Editor of the Journal of the Water Pollution Control Federation in proper form, for publication in that JOURNAL. One copy of the paper, complete with diagrams, charts, sketches, and bibliography, shall be submitted.

3. The Editor of the Journal of the Water Pollution Control Federation shall judge the suitability of any paper for publication. In case any paper is rejected, the Editor shall notify the author within thirty days of the reasons for rejection. Should any disagreement between the Editor and author arise regarding publication, the matter shall be referred to the Publications Committee for adjudication and its decision shall be final.

4. The Editor of the JOURNAL shall make any editorial changes in format or content which he may consider necessary and these shall be referred to the author in galley proof. Objections to editorial changes shall be referred by the author within seven days to the Editor and the Publications Committee and the decision of the Publications Committee shall be final.

5. The date of publication of any paper shall be left to the discretion of the Editor of the JOURNAL. Any questions regarding date of publication shall be referred to the Publications Committee and its decision shall be final.

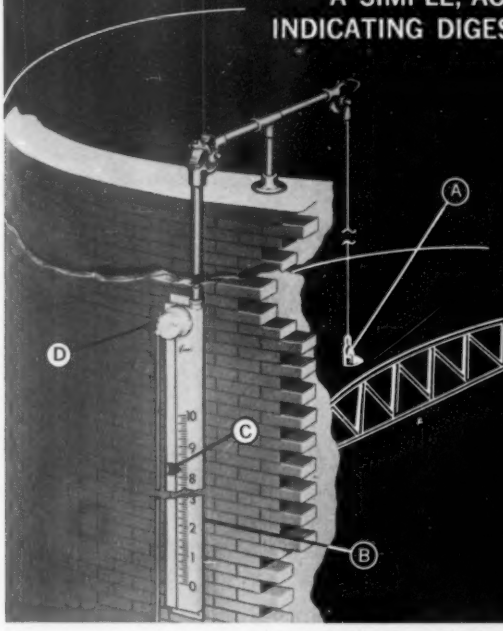
6. Papers for publication in the Journal of the Water Pollution Control Federation which have not been presented at a meeting of the Federation or of any Member Association shall be referred to the Editor for decision as to their suitability for publication. Any disagreement between the author and the Editor relative to the publication of such papers shall be referred to the Publications Committee and its decision shall be final.

7. Special publications issued in the name of the Water Pollution Control Federation shall be referred to the Editor and Publications Committee for review prior to publication.

In interpreting the above rules, there is no intent to interfere with the production of proceedings, bulletins, or reports wherein the Member Association distributes the papers presented at its meetings to its own membership. Where any doubt arises in regard to the interpretation of these rules it is suggested that the matter be taken up with the Executive Secretary-Editor of the Federation.

VAREC INDICATOR

A SIMPLE, ACCURATE METHOD FOR INDICATING DIGESTER COVER POSITION



Ⓐ Steel cable that runs from cover connection to counter-weight powered working mechanism

Ⓑ Gauge Board

Ⓒ Red Pointer

Ⓓ Electrical high-low limit switch—in explosion-proof housing—used to actuate alarms (optional).

Varec's economical gauge board indicator accurately gauges the movement of floating cover digesters with a simple working mechanism... displays readings on a 12-foot, easy-to-read anodized aluminum gauge board installed directly outside the digester.

The calibrated gauge board shows measurements in feet and inches... has a 10-foot range with an extra 2 feet of pointer measurement for greater cover or overflow travel. It provides 'quick-at-a-glance' reading with a bright red pointer that contrasts sharply against the white aluminum board and large, black numerals. All parts are ruggedly constructed and the working mechanism is enclosed in a protective housing.

VAREC OFFERS POSITION INDICATORS FOR ALL DIGESTER COVER NEEDS...

Other Varec cover position indicators include a dial type indicator that registers indication within a 10-foot range on a large, easily read dial and can be equipped with alarm switches. And, for remote control reading, Varec provides a highly-accurate gauge head indicator that delivers gauging accuracy to ½ inch... adapts for use with electrical or pneumatic remote reading or control equipment.

For complete information on all Varec digester cover position indicators, write for Varec Catalog No. S-4, Dept. JWP-1221-9

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NEW MANUAL AVAILABLE

MOP 9—SEWER DESIGN AND CONSTRUCTION

"Design and Construction of Sanitary and Storm Sewers," issued in 1960 in cooperation with the American Society of Civil Engineers, is MOP 9 in the Federation "Manuals of Practice" series.

Detailed coverage of project planning, investigations, hydraulics, design, construction materials and methods, specifications, structural requirements of storm and sanitary sewers, and pumping stations are included in this illustrated, 283-page manual.

A 1961 reprinting is now off the press with corrections to several pages. For those with the 1960 edition, a complimentary reprint of the corrected pages is available. This reprint can be cut apart and pasted over the pages to be corrected.

An order form is included on the Publications page in the back of this issue. The list price is $7.00 postpaid when remittance is with order. For Federation members the price is $3.50.

WATER POLLUTION CONTROL FEDERATION

4435 Wisconsin Avenue Washington 16, D.C.

2 new manuals—

UTILITIES ACCOUNTING MANUAL

PLANT OPERATION MANUAL

manual of practice 10

Uniform System of Accounts for Wastewater Utilities

A 72-page, completely revised version of the 1949 accounting manual.

Provides the entire accounting procedure for a wastewater utility.

For members, $2.00; for others, $3.00.

manual of practice 11

Operation of Wastewater Treatment Plants

Several years in preparation—recently serialized in the Journal—now available as a bound manual.

A well-illustrated manual of nearly 200 pages, packed with information of real help to the plant operator.

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Water Pollution Control Federation
4435 Wisconsin Avenue, Washington 16, D. C.

Enclosed is remittance for $.....If invoice is required postage will be added. Checks may be made payable to WPCF.

Please send.....copies MOP-10; .....copies MOP-11.

Member Association.....

Name.....
(please print)

Street.....

City.....Zone.....State.....

WATER POLLUTION CONTROL PRODUCT GUIDE

This list of products and services is offered as an information aid. The list was derived by solicitation from those firms listed. The JOURNAL will make every effort to keep this list current with the help of Associate Members and advertisers. All Associate Members and all advertisers for the past year are included. Many of the services and products are advertised in this issue. For an alphabetical listing see Index to Advertisers in back of JOURNAL. Write to the Federation office for complete address and representative.

Aerators (*also see* Diffusers, Air)
Alpha Ltd. (Switzerland)
American Well Works
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Graver Water Conditioning Co.
Infilco Inc.
Link-Belt Co.
Pacific Flush Tank Co.
Permutit Co., Div. of Pfaudler Permutit Inc.
Smith & Loveless
Walker Process Equipment Inc.
Wemco Div., Western Machinery Co.
Yeomans Brothers Co.
Zimmer & Francescon

Agitators
Link-Belt Co.

Air Cleaning Equipment
Westinghouse Electric Corp.

Air Compressors (*also see* Blowers, Compressors, and Fans)
Chicago Pump Co.
Fairbanks, Morse & Co.
Komline-Sanderson Engr. Corp.
Worthington Corp.
Yeomans Brothers Co.

Air Diffusers (*see* Diffusers, Air)

Asbestos Cement Pipe Products
Filtration Equipment Corp.
Industrial Materials Co.
Johns-Manville Sales Corp.
Keasbey & Mattison Co.

Ash Handling Equipment
Link-Belt Co.

Bearings
Link-Belt Co.

Bins, Storage (*see* Tanks)

Biologists (*see* Professional Services, elsewhere in this issue)

Blowers (*also see* Air Compressors, Compressors, and Fans)
Chicago Pump Co.
Roots-Connersville Blower, Div. of Dresser Industries Inc.
Sutorbilt Corp.
Walker Process Equipment Inc.
Yeomans Brothers Co.
Zimmer & Francescon

Boilers
Combustion Engineering, Inc.

Building Maintenance Equipment and Supplies
Homestead Valve Mfg. Co.

Cast Iron Pipe Products
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
Industrial Materials Co.
U. S. Pipe & Foundry Co.
R. D. Wood Co.

Cement (*see* Concrete)

Centrifuging Equipment
Bird Machine Co.
Permutit Co., Div. of Pfaudler Permutit Inc.

Chains
Chain Belt Co.
Link-Belt Co.

Chemical Feed Equipment
Builders-Providence Div., B-I-F Industries
Capital Controls Co., Inc.
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PROCEEDINGS OF MEMBER ASSOCIATIONS

NEW JERSEY WATER POLLUTION CONTROL ASSOCIATION

The 46th Annual Meeting of the New Jersey Water Pollution Control Association was held at the Traymore Hotel, Atlantic City, Mar. 15–17, 1961. Attendance totaled 510, of which 58 were ladies.

The Federation exhibit received much attention and favorable comment. Robert A. Canham of the Federation staff was present to give information about the exhibit to those who visited it.

Mark D. Hollis, Federation Past President, presented greetings from the Federation and also a report on the National Conference on Water Pollution Control. He presented the Bedell Award to Andrew Palmer, Superintendent and Secretary of the Joint Meeting of Plainfield, Dunellen; and the Hatfield Award to Edward F. Lawler, Superintendent of the sewage treatment plant and sanitary sewers of Little Falls. Dr. Hollis noted many favorable comments about the name change of both the Federation and the local Association.

Papers of interest were:

"Stream and Estuary Oxygen Balance," by Donald J. O'Connor, Assistant Professor, Department of Civil Engineering, Manhattan College, New York, N. Y.

(*Continued on page 647a*)

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Engineering News-Record
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"Microbiology of the Purification of Water," by H. Heukelekian, Chairman, Department of Sanitation, Rutgers University, New Brunswick.

"The New Jersey Program," by Robert S. Shaw, Assistant Director, Division of Environmental Health, Trenton.

"Local Action Through Watershed Operation," by Robert J. Budrick, Principal Sanitary Engineer, Jersey City Water Works, Boonton.

"Fish and Game Commission," by A. Heaton Underhill, Director, Department of Conservation and Economic Development, Trenton.

"The Program of the Interstate Sanitation Commission," by Thomas R. Glenn, Jr., Director, Chief Engineer, Interstate Sanitation Commission, New York, N. Y.

"Water Pollution Control Program and Responsibilities of the Public Health Service," by Sylvan C. Martin, Regional Engineer, USPHS, New York, N. Y.

"Effect of Stream Conditions on Treatment Plant Design," by John J. Baffa, Consulting Engineer, New York, N. Y.

"Rocket Propulsion Creates New Wastes Treatment Concepts," by James M. Langford, Supervisor, Waste Control, Reaction Motors, Inc., Denville.

"Some Aspects of Metering Wastes and Sewage," by H. Kipp, Sales Engineer, Simplex Valve and Meter Co., Lancaster, Pa.

"pH Control in Plant Wastes," by A. G. Van Stolk, Wallace and Tiernan Inc., Belleville.

"Modern Instrumentation on the Delaware River—Today's Watchdog for Water Quality. Tomorrow's Key to an Improved, Abundant Supply," by Frank L. Mascitti, Market Manager, Minneapolis-Honeywell Regulator Co., Philadelphia, Pa.

"Financial Aspects of the Bergen County Sewerage Authority," by Harry

(*Continued on page 649a*)

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"The Developer's Point of View on Sewage Treatment Problems," by Richard C. Goodwin, President, Goodwin Homes, Inc., Haddonfield.

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The 24th Annual Louisiana Conference on Water Supply and Sewerage was held Mar. 15–17, 1961, at the Louisiana State University, Baton Rouge, La. The Louisiana Conference is conducted as a short course for superintendents and operators of water, sewerage, and industrial waste disposal systems, with registration through the Extension Division of Louisiana State University. There was a record attendance of 272.

Harry E. Schlenz, WPCF Vice-President, represented the Federation. At the Annual Banquet, he spoke on water pollution control and public relations, a challenge to the profession and the Federation.

Many interesting papers were presented. Among those of particular interest were:

"Combating Septic Sewage Problems," by James F. Coerver, Chief, Water Supply and Waste Disposal Sec-

(*Continued on page 651a*)

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tion, Louisiana State Board of Health.

"Sewage Collection System Maintenance," by Edmond E. Dupre, Superintendent, Sewerage Department, Lafayette.

"Maintenance and Operation of Oxidation Ponds," by A. B. Ritter, Chief, Insect Vector and Rodent Control Section, State Board of Health.

"Removal of Color from Kraft Pulp Mill Effluents," by Herbert F. Berger, Regional Engineer, National Council for Stream Improvement; and Albert J. Herbert, Research Associate, Louisiana State University, Engineering Experiment Station.

"Flow Measurement Techniques," by Gerald D. Healy, Jr., Regional Engineer, State Board of Health, Monroe.

"Underground Disposal of Oil Refinery Sour Water Wastes," by Ben Graves, Supervisor of Waste Disposal, Shell Oil Co., Norco.

"Recent Field and Laboratory Activities of the Division of Water Pollution Control," by Richard Gregg, Biologist, Division of Water Pollution Control, Louisiana Wild Life and Fisheries Commission.

"The Biological Filtration Process," by William A. Wintz, Associate Professor of Civil Engineering, Louisiana State University.

"Water and Sewerage Works Assistance Programs," by John T. Chambers, Jr., Public Health Engineer, State Board of Health.

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(*Continued on page 652a*)

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WEST VIRGINIA WATER POLLUTION CONTROL ASSOCIATION

The 15th Annual Meeting of the West Virginia Water Pollution Control Association was held in conjunction with the 33rd Annual Meeting of the West Virginia Section of the American Water Works Association. The joint meeting was held at the West Virginian Hotel, Bluefield, W. Va., Apr. 6–7, 1961. Attendance at the meeting totaled 165 men and 21 ladies.

Harry E. Schlenz, WPCF Vice-President, represented the Federation at the meeting. His discussion at the Thursday Joint Luncheon covered Federation activities, challenges in the water pollution control field, the National Conference, legislation, and others.

Papers of interest included:

"Financing Water Works and Sewage Treatment Works Improvements," by Houston G. Young, Attorney, Young, Moore, and Co., Inc., Charleston.

"Progress in Municipal and Industrial Wastes Treatment in West Virginia, Including Stabilization Ponds," by Edgar N. Henry, Engineer, State Water Resources Commission, Charleston; and Glen O. Fortney, Chief Engineering Station, Division of Sanitary Engineering, State Department of Health, Charleston.

At the business meeting the following officers were elected to serve for 1961–62:

President: Richard L. Williams, South Charleston.

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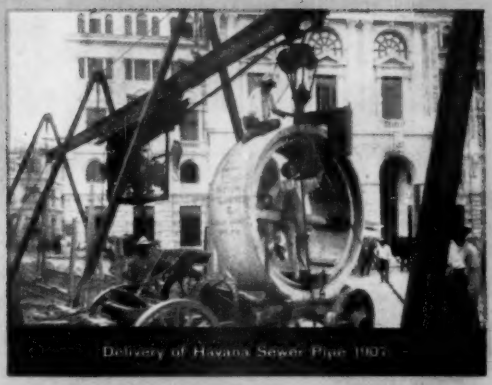

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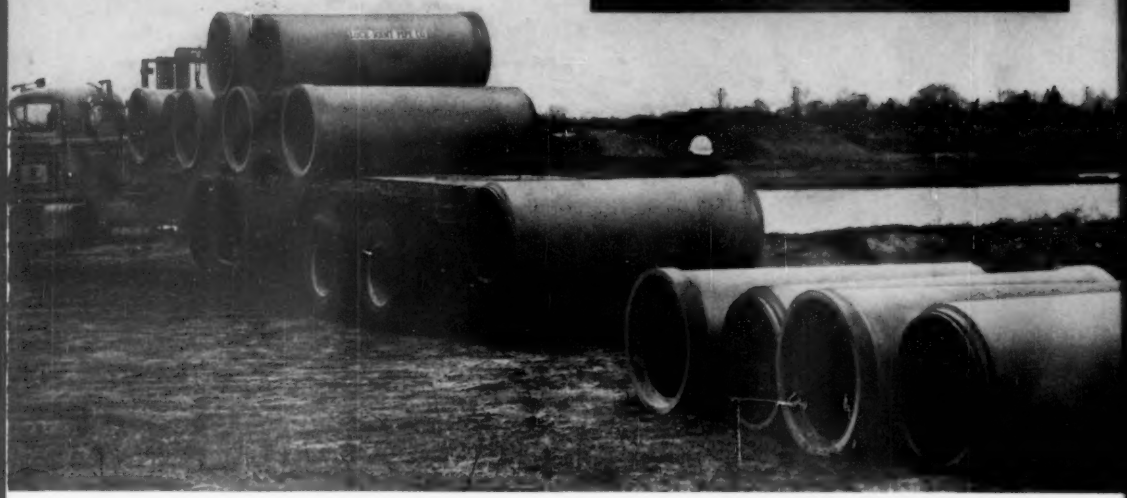

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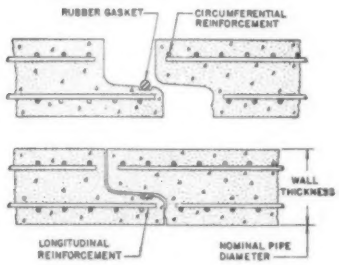

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